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DESCRIPTION

HIGH DIMENSIONAL ACCURACY PIPE, MANUFACTURING METHOD THEREOF, AND MANUFACTURING APPARATUS

Technical Field

The present invention relates to high dimensional accuracy pipes, manufacturing methods thereof, and manufacturing apparatuses. The present invention relates to a high dimensional accuracy pipe applicable to components, such as drive train parts for automobile, which require high dimensional accuracy, a manufacturing method thereof, a manufacturing apparatus, and a manufacturing line.

Background Art

In general, a metal pipe such as a steel pipe is roughly classified into a welded pipe and a seamless pipe. As is an electric-resistance welded pipe, the welded pipe is manufactured in a manner in which a band plate is roundly bent in the width direction, and two ends of the rounded band plate are brought into contact with each other and are then welded together. On the other hand, the seamless pipe is manufactured by piercing a billet at a high temperature, followed by rolling using a mandrel mill or the like. In the case of the welded pipe, the dimensional accuracy is

improved by grinding a protrusion at a welded portion after welding; however, the deviation of the thickness exceeds 3.0%. In addition, in the case of the seamless pipe, it is very likely that an eccentricity is introduced in a piercing step, and thereby the thickness is liable to be more largely deviated. Although efforts have been made in order to reduce the deviation of the thickness, a sufficient reduction thereof has not been obtained as of today, and as a result, the deviation is still 8.0% or more as the finished product.

Recently, as measures for environment-related issues, weight reduction of automobiles has been seriously desired. As for drive train parts such as a drive shaft, hollow metal pipes have been progressively increased instead of solid metal bars. The metal pipes used, for example, for the drive train parts for automobile are required to have high dimensional accuracy so that the deviations of the thickness, inner diameter, and outer diameter are each 3.0% or less and more strictly 1.0% or less.

The drive train parts must withstand fatigue caused by long-run driving of automobile. When the accuracy of the thickness, inner diameter, and outer diameter of a metal pipe is inferior, the fatigue failure is inevitably liable to progress from irregularities present on the interior and exterior surfaces of the pipe, and as a result, the fatigue

strength is extremely decreased. For maintaining a sufficient fatigue strength, the accuracy of the thickness, inner diameter, and outer diameter of the metal pipe must be improved.

Hereinafter, the high dimensional accuracy pipe of the present invention indicate a pipe in which at least one of the deviations of the outer diameter, inner diameter, and thickness in the circumferential direction is 3.0% or less, and the deviations are each obtained by the following equations.

Deviation = Amount of fluctuation/(target value or average value) × 100%

Amount of fluctuation = maximum value - minimum value

As means for improving the accuracy of the thickness, inner diameter, and outer diameter of a metal pipe, in general, two methods have been known. Hereinafter, a welded steel pipe and a seamless pipe (hereinafter referred to as a steel pipe or a pipe) will be described. One of the above two is a method (so-called cold drawing method) in which a steel pipe is cold-drawn using a die and a plug (see Patent Document 5). The other one is a method (so-called rotary press forging method) in which a steel pipe is pressed in a die hole using a rotary forging device incorporating a segmented die which is segmented in the circumferential direction (see Patent Documents 1, 2, and 3).

Patent Document 1: Japanese Unexamined Patent Application Publication No. 9-262637

Patent Document 2: Japanese Unexamined Patent Application Publication No. 9-262619

Patent Document 3: Japanese Unexamined Patent Application Publication No. 10-15612

Patent Document 4: Japanese Patent No. 2858446

Patent Document 5: Japanese Patent No. 2812151

However, in the cold drawing method, when production capacity is insufficient, or when a diameter reduction rate must be decreased since a sufficient drawing stress cannot be obtained due to excessively large thickness and diameter of a pipe, the contact between a die and the pipe and that between a drawing plug and the pipe in a processing tool (a space between the plug and the interior surface of the die hole) become insufficient. The reason for this is that the stress of the pipe in the cold drawing method is a tensile force. In this case, the smoothness of the interior surface and the exterior surface of the pipe are not satisfactory, and as a result, irregularities are liable to remain thereon. As measures therefor, the diameter reduction rate of the pipe by the cold drawing method is increased so as to increase the contact of the interior and exterior surfaces of the pipe with the plug and die in the processing tool. However, when a pipe is cold-drawn using a die, as the

diameter reduction rate thereof is increased, the roughness is increased due to the irregularities of the interior surface of the pipe. As a result, it is difficult to obtain a high dimensional accuracy pipe by the cold drawing method. Hence, the fatigue strength of the pipe is not satisfactory, and a pipe having superior dimensional accuracy has been more strongly desired. In the cold drawing method, since being held for application of a tensile force, the front end of a pipe must be made narrower. As a result, since drawing must be performed for one pipe at a time, a problem has occurred in that the process efficiency is extremely poor.

In addition, even when the production capacity is high, and the diameter reduction rate can be increased, processing strain caused by the diameter reduction is increased, and as a result, work hardening of a pipe is liable to occur. After the drawing, the pipe is further processed by bending or swaging. There has been a problem in that cracking is liable to occur in a subsequent bending step due to work hardening in the drawing described above. In order to avoid the problem described above, heat treatment must be performed for a sufficiently long time at a high temperature after the drawing, and as a result, the production cost is very much increased. Hence, a method for manufacturing a high dimensional accuracy pipe, which is inexpensive and has superior workability, with a high efficiency has been

eagerly desired.

A pressure device for a metal pipe described in patent Document 4 is an auxiliary device having functions in which, while the metal pipe is being drawn by a different device, the pipe is prevented from being broken caused by the above drawing and in which a tensile force required for forming a groove in the interior surface of the pipe is decreased. Hence, the pressure device described above is not a device for smoothing the interior and the exterior surfaces of the pipe.

In the rotary press forging method described in Patent Documents 1 to 3, since a die of a rotary forging device is segmented and is rocked, steps are easily formed at the segmented portions, and the smoothness of the exterior surface may become insufficient, or due to the difference in rigidity of the die in the circumferential direction, non-uniform deformation may occurs in some cases. As a result, the thickness accuracy also becomes unsatisfactory, a targeted finish dimensional accuracy cannot be sufficiently obtained, and the fatigue strength of the steel pipe is also not enough; hence, the improvement has been desired.

In the rotary press forging method, the thickness of a pipe after being pressed is larger than that before being pressed. This is because of the restriction caused by the use of a rotary forging device in which it is difficult to

apply a force due to a complicated structure thereof. In order to increase the thickness, the space at the side close to an outlet of the processing tool is increased so that the pipe is easily deformed; however, when the space is provided, and the deformation easily occurs, irregularities are generated on the interior surface of the pipe. When the thickness is further increased, the space is increased, and as a result, the pipe is not sufficiently brought into contact with a die surface and/or a plug surface. As a result, the smoothing of the pipe surface is not improved, and hence a problem is encountered in that a high dimensional accuracy pipe is unlikely to be obtained.

In addition, in manufacturing a high dimensional accuracy pipe, when a friction force between the exterior surface of the plug and the interior surface of the pipe and that between the interior surface of the die and the exterior surface of the pipe are not decreased as small as possible, faults such as burn marks are generated on the surface of the pipe in processing, and the surface quality of the pipe after processing is degraded, so that the pipe thus obtained cannot be formed into a product. In addition to that described above, a load in processing is extremely increased, and it may become impossible to continue the process itself in some cases, resulting in extreme decrease in production efficiency.

Accordingly, in order to obtain a desired thickness after a pipe is pressed, the thickness thereof before it is pressed must be inevitably decreased. Hence, in order to prepare pipes having various product sizes and to improve properties thereof such as the fatigue strength, many raw pipe sizes must be prepared. However, many sizes cannot be prepared due to the restriction by raw-pipe production facilities, and hence it has been difficult to obtain pipes having superior dimensions which can respond to all the required sizes. In addition, also for automobile parts, pipes having different degrees of processing are used. For example, for a certain part, it has been considered in some cases to omit heat treatment after processing by decreasing the degree of processing, and for another part, the strength is increased by significantly increasing the degree of processing.

However, according to a conventional cold drawing method and rotary press forging method, since only a diameter reduction process has been performed, the outer diameter of a processed pipe is primarily determined by a die diameter, and the thickness is also primarily determined by a die and a plug. Hence, from identical pipes, only one particular degree of processing is obtained, and it has been almost impossible to manufacture pipes having the same size and different degrees of processing from identical raw pipes.

Accordingly, in order to manufacture pipes having the same size and different degrees of processing, raw pipes having plural sizes must be inevitably prepared so as to change the diameter reduction rate thereof, and as a result, manufacturing of raw pipes requires lots of time and effort.

As described above, a high dimensional accuracy pipe is difficult to obtain by conventional techniques, and in addition, a problem has occurred in that when pipes having the same size and different degrees of processing are manufactured, many raw pipes having different sizes must be prepared.

In order to solve the above problems, research was carried out by the inventors of the present invention on methods for forming a pipe having a higher dimensional accuracy than that obtained by drawing, and finally, it was found that a push-to-pass process is a potential candidate. In the case of the push-to-pass process, as shown in Fig. 10, since a plug 1 is charged in a pipe 4, and the pipe 4 is pushed in a die 2 by a pipe pushing device 3 while the plug 1 is being floated, a compressive force works in the entire processing tool. As a result, regardless of an inlet side and an outlet side of the processing tool, the pipe can be sufficiently brought into contact with the plug and the die. Furthermore, even when the diameter reduction rate is small, since the inside of the processing tool is placed in a

compressed stress state, compared to the case of drawing, the pipe are likely to be sufficiently brought into contact with the plug and the die, and hence the pipe is likely to be smoothed, thereby obtaining a high dimensional accuracy pipe.

However, in performing the push-to-pass process, the following case occurred. That is, the plug clogged the pipe to increase a load, the raw pipe which was pushed was buckled, and hence the process could not be further continued. As the reasons for this, for example, there may be mentioned an insufficient amount of lubricant applied onto the raw pipe, the change in surface condition of the raw pipe, and deformation of the plug or die due to frictional heat or process heat generated in the push-to-pass process. However, in order to continue a stable push-to-pass process for pipes, whether the process can be continue or not must be first determined in situ during the process.

Heretofore, after the above determination was sensuously made by an operator in consideration of noise of a pipe pushing device, fluctuation shown by oil-pressure meters, and the like, or the process was stopped due to die cracking caused by a process which was forcedly continued, push-to-pass conditions were reviewed, and the process was then restarted. That is, even when the process was

performed under conditions much milder than the upper limit of the push-to-pass process standard, the conditions were changed, or when the die was cracked under extremely severe process conditions, the conditions were then first changed. Hence, an unnecessary process time was increased, or a time for exchanging the die was extremely increased, and as a result, a low productivity has not been improved as of today.

In conventional drawing, in order to improve the dimensional accuracy of a pipe, after bonderizing treatment was performed for a pipe before drawing, it was necessary that metal soap be applied thereto so as to form a sufficient lubricant film. Accordingly, a sufficient time was required for forming the lubricant film, and in addition, pretreatment of the pipe, such as pickling, was also required; hence, in a manufacturing line for drawing, a plurality of baths for pretreatment such as pickling and a plurality of baths for lubricant treatment were required. In addition, for performing the drawing process, metal pointing was necessarily performed for the front end of the pipe by using a rotary forging device or the like. However, when the above manufacturing line is allowed to go online and is arranged at an inlet side of a drawing process device, the productivity is decreased, thereby causing a serious problem. Hence, the lubrication treatment was performed in a separate process, and the pipes thus treated were then

introduced in the online manufacturing line of drawing for processing.

That is, in a conventional manufacturing line for a high dimensional accuracy pipe, since the drawing which requires a long pretreatment process must be performed, it has been difficult to improve the production efficiency.

As described above, according to the conventional cold drawing method and rotary press forging method, a high dimensional accuracy pipe is difficult to obtain, and in addition, the problem has not still been solved in that the surface quality of a pipe may be degraded in some cases. In consideration of the problems of the conventional techniques described above, an object of the present invention is to provide high dimensional accuracy pipes, a manufacturing method thereof, and a manufacturing line for performing manufacturing with high efficiency, the high dimensional accuracy pipes capable of meeting wide requirements of sizes, being manufactured at inexpensive cost, and having a sufficient fatigue strength.

Disclosure of Invention

The present invention which achieved the above objects is as follows.

1. A high dimensional accuracy pipe manufactured by a push-to-pass process comprising the steps of pushing at

least one metal pipe in a hole provided in a die while a plug is being charged in the metal pipe, and allowing the metal pipe to pass through the hole, wherein at least one of the deviation of the outside diameter, the deviation of the inside diameter, and the deviation of the thickness in the circumferential direction of the pipe as processed is 3.0% or less.

2. The high dimensional accuracy pipe described in 1. above, which is manufactured by a push-to-pass process comprising the steps of pushing at least one metal pipe in a hole provided in a die while a plug is being charged in the pipe, and allowing the metal pipe to pass through the hole so that the thickness of the metal pipe at an outlet side of the die is not more than that at an inlet side, wherein at least one of the deviation of the outside diameter, the deviation of the inside diameter, and the deviation of the thickness in the circumferential direction of the pipe as processed is 3.0% or less.

3. The high dimensional accuracy pipe described in 1 or 2 above, wherein the push-to-pass process is performed while the metal pipe is being in contact with the entire outer circumference of the plug and with the entire inner circumference of the die in the same cross-section of the metal pipe.

4. The high dimensional accuracy pipe described in one of

1. to 3. above, wherein the die is an all-in-one type and/or a fixed type die.

5. A method for manufacturing a high dimensional accuracy pipe, comprising a push-to-pass process which comprises the step of pushing at least one metal pipe in a hole provided in a die while a plug is being charged in the metal pipe, and allowing the metal pipe to pass through the hole.

6. The method for manufacturing a high dimensional accuracy pipe, described in 5 above, wherein the thickness of the pipe at an outlet side of the die is set not more than that at an inlet side thereof.

7. The method for manufacturing a high dimensional accuracy pipe, described in 5. or 6. above, wherein the push-to-pass process is performed while the metal pipe is being in contact with the entire outer circumference of the plug and with the entire inner circumference of the die in the same cross-section of the metal pipe.

8. The method for manufacturing a high dimensional accuracy pipe, described in one of 5 to 7 above, wherein the die is an all-in-one type and/or a fixed type die.

9. The method for manufacturing a high dimensional accuracy pipe, described in one of 5. to 8. above, wherein the plug is a floating plug.

10. A highly efficient method for manufacturing a high dimensional accuracy pipe, wherein, in 5. above, when at

least one of the deviation of the outside diameter, the deviation of the inside diameter, and the deviation of the thickness in the circumferential direction of each of the pipes is improved by the push-to-pass process, the pipes are continuously fed in the die using pipe-feeding means provided at an inlet side of the die while the plug is being charged in each of the pipes and is being floated.

11. The highly efficient method for manufacturing a high dimensional accuracy pipe, described in 10. above, wherein the pipe feeding means is at least one caterpillar holding the pipes before they are processed.

12. The highly efficient method for manufacturing a high dimensional accuracy pipe, described in 10. above, wherein the pipe feeding means is at least one endless belt holding the pipes before they are processed.

13. The highly efficient method for manufacturing a high dimensional accuracy pipe, described in 10. above, wherein the pipe feeding means is at least one intermittent feeding device which alternately holds and intermittently feeds the pipes before they are processed.

14. The highly efficient method for manufacturing a high dimensional accuracy pipe, described in 10. above, wherein the pipe feeding means is a press which sequentially pushing the pipes before they are processed.

15. The highly efficient method for manufacturing a high

dimensional accuracy pipe, described in 10. above, wherein the pipe feeding means is at least one grooved roll holding the pipes before they are processed.

16. The highly efficient method for manufacturing a high dimensional accuracy pipe, described in 15 above, wherein the number of said at least one grooved roll is at least two.

17. The highly efficient method for manufacturing a high dimensional accuracy pipe, described in 15 or 16 above, wherein at least two stands each having the grooved roll are provided.

18. A method for manufacturing a high dimensional accuracy pipe having superior surface quality, wherein, in 5. above, after an interior and/or an exterior surface of the pipe is provided with a lubricant film, the plug is charged in the pipe, and the push-to-pass process is performed using the die.

19. The method for manufacturing a high dimensional accuracy pipe having superior surface quality, described in 18. above, wherein the pipe on which the lubricant film is formed is a steel pipe to which oxide scales still adhere.

20. The method for manufacturing a high dimensional accuracy pipe having superior surface quality, described in 18. or 19. above, wherein the lubricant film is formed by using a liquid lubricant.

21. The method for manufacturing a high dimensional

accuracy pipe having superior surface quality, described in 18. or 19. above, wherein the lubricant film is formed by using a grease-based lubricant.

22. The method for manufacturing a high dimensional accuracy pipe having superior surface quality, described in 18. or 19. above, wherein the lubricant film is formed by using a drying resin.

23. The method for manufacturing a high dimensional accuracy pipe having superior surface quality, described in 22 above, wherein the lubricant film is formed by the steps of applying the drying resin, a liquid containing the drying resin diluted with a solvent, or an emulsion of the drying resin, and then supplying a hot wind or performing air drying.

24. A method for manufacturing a high dimensional accuracy pipe, wherein, in 5. above, in a high dimensional accuracy pipe manufacturing method for manufacturing pipes having a predetermined size and different degrees of processing with high dimensional accuracy from raw pipes having the same size, a plug capable of expanding the pipes and reducing the diameters thereof is charged in the pipes, and the push-to-pass process is performed for the pipes using the die.

25. The method for manufacturing a high dimensional accuracy pipe, described in 24. above, wherein the plug is

floated in the pipes, and the pipes are continuously supplied to the die.

26. The method for manufacturing a high dimensional accuracy pipe, described in 24. or 25. above, wherein the plug is a plug in which a corn angle at a pipe expanding portion is set to be smaller than a corn angle at a diameter reducing portion.

27. The method for manufacturing a high dimensional accuracy pipe, described in one of 24. to 26. above, wherein a target outside diameter of the pipe at an outlet side of the die is set to be smaller than the outside diameter of the pipe at an inlet side of the die.

28. A stable method for manufacturing a high dimensional accuracy pipe, wherein, in 5. above, in manufacturing a high dimensional accuracy pipe by the push-to-pass process in which, while the plug is being charged in the pipe, the pipe is pushed in the hole provided in the die and is then allowed to pass therethrough, a plug having an angle of 5 to 40° which is formed between the surface of a diameter reducing portion and a processing central axis and a length of 5 to 100 mm of the diameter reducing portion is used as the plug, and as the die, a die is used having an angle of 5 to 40° which is formed between the interior surface of the hole at an inlet side and the processing central axis.

29. The stable method for manufacturing a high

dimensional accuracy pipe, described in 28. above, wherein the length of a bearing portion of the plug is set to 5 to 200 mm.

30. The stable method for manufacturing a high dimensional accuracy pipe, described in 28. or 29. above, wherein the thickness of the pipe at an outlet side of the die is set to be not more than that at an inlet side thereof.

31. The stable method for manufacturing a high dimensional accuracy pipe, described in one of 28. to 30. above, wherein as the die, an all-in-one fixed type die is used.

32. The stable method for manufacturing a high dimensional accuracy pipe, described in 28 or 31 above, wherein the plug is being floated in the pipe.

33. A stable method for manufacturing a high dimensional accuracy pipe, wherein, in 5. above, in manufacturing a high dimensional accuracy pipe by the push-to-pass process in which, while the plug is being charged in the pipe and is being floated, the pipe is pushed in the hole provided in the die and is then allowed to pass therethrough, during the push-to-pass process, a load in a push-to-pass direction is measured, the measured load is compared with a calculated load calculated using one of the following [equation 1] to [equation 3] obtained from material properties of a raw pipe, which is a pipe before processing, and the continuation of

the push-to-pass process is determined based on the result of the comparison;

Note

[Equation 1] σ_k × the cross-section of a raw pipe

In the above equation, $\sigma_k = YS \times (1 - a \times \lambda)$, $\lambda = (L/\sqrt{n})/k$, a=0.00185 to 0.0155, L represents the length of the raw pipe, k represents the secondary radius of the cross-section, $k^2 = (d_1{}^2 + d_2{}^2)/16$, n represents pipe end conditions (n=0.25 to 4), d_1 represents the outer diameter of the raw pipe, d_2 represents the inner diameter of the raw pipe, and YS represents a yield strength of the raw pipe;

[Equation 2] yield strength YS of the raw pipe × the cross-section of the raw pipe; and

[Equation 3] tensile strength TS of the raw pipe × the cross-section of the raw pipe.

34. The stable method for manufacturing a high dimensional accuracy pipe, described in 33. above, wherein, when the measured load is not more than the calculated load, it is determined that the continuation can be performed, so that the process is continued as it has been, and when the measured load is more than the calculated load, after it is determined that the continuation cannot be performed, and the process is then interrupted so that the die and/or the plug is exchanged with a new one which has a different shape in conformity with the same pipe product dimensions, the

process is restarted.

35. The stable method for manufacturing a high dimensional accuracy pipe, described in 34. above, wherein the die and the plug to be used after the exchange have angles smaller than those of the die and the plug used before the exchange.

36. The stable method for manufacturing a high dimensional accuracy pipe, described in one of 33. to 35. above, wherein a lubricant is applied onto the raw pipe before the push-to-pass process, and only when the measured load exceeds the calculated load, the type of lubricant is changed.

37. A manufacturing apparatus for manufacturing a high dimensional accuracy pipe, comprising: a plug capable of being in contact with the entire inner circumference of at least one metal pipe, at least one die having a hole capable of being in contact with the entire outer circumference of the metal pipe, and a pipe pushing device pushing the metal pipe, wherein while the plug is being charged in the metal pipe, the metal pipe is pushed in the hole in the die and is then allowed to pass therethrough, whereby the push-to-pass process is performed.

38. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in 37. above, wherein the die is an all-in-one type and/or a fixed type die.

39. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in 37 or 38. above, wherein the plug is a floating type plug.

40. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in one of 37. to 39., wherein the pipe pushing device is a device continuously pushing the metal pipes.

41. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in one of 37. to 39. above, wherein the pipe pushing device is a device intermittently pushing the metal pipes.

42. A highly efficient manufacturing method for manufacturing a high dimensional accuracy pipe, wherein, in 37. above, in a manufacturing method for manufacturing a high dimensional accuracy pipe, in which a plug is charged in pipes and is floated, and the pipes are continuously or intermittently pushed in a die and are then allowed to pass therethrough so as to perform a push-to-pass process, a plurality of dies having different hole shapes is arranged along the same circumference, and one of the dies in conformity with product dimensions is moved in the circumference direction of the arrangement and is disposed in a pass line so that the push-to-pass process is performed.

43. A highly efficient manufacturing method for manufacturing a high dimensional accuracy pipe, wherein, in

37. above, in a manufacturing method for manufacturing a high dimensional accuracy pipe, in which a plug is charged in pipes and is floated, and the pipes are continuously or intermittently pushed in a die and are then allowed to pass therethrough so as to perform a push-to-pass process, a plurality of dies having different hole shapes is arranged on the same linear line, and one of the dies in conformity with product dimensions is moved in the linear line direction of the arrangement and is disposed in a pass line so that the push-to-pass process is performed.

44. The highly efficient manufacturing method for manufacturing a high dimensional accuracy pipe, described in 42. or 43. above, wherein when production dimensions for the following pipe are changed from those for the preceding pipe, after the push-to-pass process for the preceding pipe is performed, the following pipe is allowed to stay at an inlet side of the die, and before or after a die in conformity with the production dimensions for the following pipe is moved or while the die is being moved, a plug in conformity with the same production dimensions is charged in the following pipe.

45. A highly efficient manufacturing apparatus for manufacturing a high dimensional accuracy pipe, wherein, in 37. above, the dies through which the pipes are allowed to pass, the pushing device pushing the pipes in a die placed

in a pass line, and a die rotating platform are provided, the die rotating platform supporting the dies arranged in the same circumference and moving one of the dies in a circumference direction to dispose it in the pass line.

46. A highly efficient manufacturing apparatus for manufacturing a high dimensional accuracy pipe, wherein, in 37. above, above, the dies through which the pipes are allowed to pass, the pushing device pushing the pipes in a die placed in a pass line, and a die linear-driving platform are provided, the die linear-driving platform supporting the dies arranged on the same linear line and moving one of the dies in a linear line direction to dispose it in the pass line.

47. A manufacturing method for manufacturing a high dimensional accuracy pipe, wherein, in 5. above, in a manufacturing method for manufacturing a high dimensional accuracy pipe by the push-to-pass process in which, while the plug is charged in the pipe and is floated, the pipe is pushed in the die and is then allowed to pass therethrough, the pipe at an outlet side of the die is allowed to pass through a hole body provided at a position which is very close to the outlet side of the die and which is adjusted beforehand in the plane perpendicular to a pipe traveling direction, whereby pipe bending is prevented.

48. The manufacturing method for manufacturing a high

dimensional accuracy pipe, described in 47 above, wherein the pipe at an inlet side of the die and/or an outlet side of the hole body is allowed to pass through a guide tube.

49. The manufacturing method for manufacturing a high dimensional accuracy pipe, described in 47. or 48. above, wherein the pipes are continuously pushed in the die.

50. A manufacturing apparatus for manufacturing a high dimensional accuracy pipe, wherein, in 37. above, in a manufacturing apparatus having the die through which the pipe is allowed to pass, and the pushing device pushing the pipe in the die, fine adjustment means for adjusting pipe bending is provided at a position very close to an outlet side of the die, the means having a hole body through which the pipe is allowed to pass, a support substrate supporting the hole body movably in the plane perpendicular to a pipe traveling direction, and a hole body-moving mechanism which is supported by the support substrate and which moves the hole body.

51. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in 50. above, wherein the hole body-moving mechanism is a mechanism in which at least one place of a peripheral portion of the hole body is pushed in the direction perpendicular to the pipe traveling direction by a tapered surface of a wedge-shaped mold which is moved in the pipe traveling direction.

52. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in 51 above, wherein the movement of the wedge-shaped mold is biased by a screw.

53. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in 50. above, wherein the hole body-moving mechanism is in accordance with a pushing or a pulling method in which at least one place of a peripheral portion of the hole body is directly pushed or pulled in the direction perpendicular to the pipe traveling direction.

54. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in 53. above, wherein the pushing or pulling of the pushing or pulling method is biased by a fluid pressure cylinder.

55. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in one of 50. to 54. above, wherein the diameter of a hole provided in the hole body is not less than the diameter of the hole in the die at the outlet side.

56. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in one of 50. to 55. above, wherein the hole in the hole body is a straight hole or a tapered hole.

57. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in one of 50. to 56.

above, wherein at least one guide tube is further provided, through which the pipe at an inlet side of the die and/or an outlet side of the fine adjustment means for adjusting pipe bending is allowed to pass.

58. The manufacturing apparatus for manufacturing a high dimensional accuracy pipe, described in one of 50. to 57. above, wherein the pushing device is a continuous pushing device capable of continuously pushing the pipes.

59. A manufacturing line for manufacturing a high dimensional accuracy pipe, comprising the push-to-pass process device described in 37. above, wherein a pipe-end grinding device grinding the end surface of the pipe in the direction perpendicular to a pipe axis, a lubricant immersion coating bath in which the pipe is coated with a lubricant by immersion, a drying device drying the pipe coated with the lubricant, and the push-to-pass process device are provided in that order.

60. The manufacturing line for manufacturing a high dimensional accuracy pipe, described in 59. above, wherein a cutting device cutting the pipe into short pipes is further provided at an inlet side of the pipe-end grinding device.

61. The manufacturing line for manufacturing a high dimensional accuracy pipe, described in 59. or 60. above, wherein, instead of the lubricant immersion coating bath and the drying device, at an inlet side of the die of the push-

to-pass process device, a lubricant spray coating device for coating the pipe with a lubricant by spraying or a lubricant spray coating and drying device in which the pipe is coated with a lubricant by spraying and is then dried is provided.

62. The manufacturing line for manufacturing a high dimensional accuracy pipe, described in one of 59. to 61., wherein, in addition to the push-to-pass process device, at least one of a die exchange device exchanging the die, a plug exchange device exchanging the plug, and a bending prevention device preventing pipe bending at an outlet side of the die is provided.

Brief Description of the Drawings

Fig. 1 is a view for illustrating an embodiment of a push-to-pass process of the present invention.

Fig. 2 is a view for illustrating an embodiment of a conventional drawing process.

Fig. 3A is a view for illustrating an embodiment of a pressing process by a rotary forging device in which a conventional segmented die is provided and is rocked, the view being a cross-sectional view including a pipe central axis.

Fig. 3B is a cross-sectional view taken along the line A-A for illustrating an embodiment of a pressing process by a rotary forging device in which a conventional segmented

die is provided and is rocked.

Fig. 4 is a characteristic graph showing the relationship between the stress and endurance cycles in a fatigue test.

Fig. 5 is a vertical cross-sectional view showing an example of the present invention using caterpillars as pipe feeding means.

Fig. 6 is a vertical cross-sectional view showing an example of the present invention using endless belts as pipe feeding means.

Fig. 7 is a vertical cross-sectional view showing an example of the present invention using intermittent feeding devices as pipe feeding means.

Fig. 8 is a vertical cross-sectional view showing an example of the present invention using grooved rolls as pipe feeding means.

Fig. 9 is a view illustrating corn angles of parts of a plug.

Fig. 10 is a cross-sectional view showing the outline of a push-to-pass process.

Fig. 11 is a schematic view showing an embodiment of a method according to the present invention using a first example of an apparatus of the present invention.

Fig. 12 is a schematic view showing an embodiment of a method according to the present invention using a second

example of an apparatus of the present invention.

Fig. 13 is a view for illustrating a comparative example (die is exchanged by hand).

Fig. 14 is a perspective view showing one of examples of the present invention.

Fig. 15 is a plan view showing one example of fine adjustment means for adjusting pipe bending, according to the present invention.

Fig. 16 is a cross-sectional view showing one example of a hole body-moving mechanism according to the present invention.

Fig. 17 is a perspective view showing one of examples according to the present invention.

Fig. 18 is a plan view showing one example of fine adjustment means for adjusting pipe bending, according to the present invention.

Fig. 19 is a perspective view showing one of comparative examples.

Fig. 20 is a perspective view showing one of comparative examples.

Fig. 21 is a perspective view showing one of comparative examples.

Fig. 22 is a schematic view showing the arrangement of a manufacturing line which is one example of the present invention.

Fig. 23 is a schematic view showing the arrangement of a manufacturing line and pre-treatment processes required for a drawing process, according to one comparative example.

Best Mode for Carrying Out the Invention

In a conventional cold drawing method, when a metal pipe is drawn out using a die and a plug, it has been difficult to improve the dimensional accuracy of the pipe. The reason for this is that since a drawing force works as a tensile force, the contact between the die and the exterior surface of the pipe and that between the plug and the interior surface of the pipe in a processing tool become insufficient. As shown in Fig. 2, when a plug 1 is charged in a pipe 5, and the pipe 5 is drawn out through a hole provided in a die 2, by a drawing force 9 applied at an outlet side of the die 2, a tensile stress is generated inside the processing tool, and as a result, irregularities are generated and increased on the interior and the exterior surfaces of the pipe from an inlet side to an outlet side of the processing tool. In addition, at the inlet side of the processing tool, since the interior surface of the pipe is deformed along the plug 1, contact of the exterior surface of the pipe is not substantially made or is only slightly made. At the outlet side of the processing tool, since the exterior surface of the pipe is in contact with the die 2

and is deformed, the contact of the interior surface of the pipe is not substantially made or is only slightly made. Hence, on both the interior and the exterior surfaces of the pipe, since portions which can be freely deformed are present, irregularities cannot be sufficiently smoothed, and as a result, the dimensional accuracy of the pipe obtained by drawing was inferior.

Compared to the method described above, according to the push-to-pass method of the present invention, as shown in Fig. 1, the plug 1 is charged in the pipe 5, and the pipe 5 is pushed in the hole provided in the die 2 and is then allowed to pass therethrough. By a pushing force 8 applied at an inlet side of the die 2, a compressive force works entirely in the processing tool. As a result, even at the inlet and outlet sides of the processing tool, the pipe 5 can be sufficiently brought into contact with the plug 1 and die 2 along the entire circumferential direction in the same cross-section. In addition, even at a small diameter reduction rate, since a compressive strength is generated inside the processing tool, compared to the drawing, the contact between the pipe and the plug and that between the pipe and the die are made along the entire circumferential direction in the same cross-section. Hence, the pipe is likely to be smoothed, and as a result, a high dimensional accuracy pipe can be obtained.

As a result, when the fatigue strengths of these pipes are compared with each other, the pipe manufactured by the push-to-pass can obtain a targeted sufficient fatigue strength as compared to that of the pipe manufactured by the conventional drawing. In addition, in the case of the push-to-pass, even at a small diameter reduction rate, since smoothing of the interior and exterior surfaces of the pipe can be performed, strain caused by the push-to-pass is not increased as compared to that of the drawing; hence, a heat treatment load after the diameter reduction is small, and the manufacturing cost can also be decreased.

In a pressing process performed by using a conventional rotary forging device 8 shown in Fig. 3, since the process is performed by rocking 12 a die which is a segmented die 9 formed by dividing an all-in-one type die in the circumferential direction, steps are formed, and as a result, the accuracy in thickness cannot be satisfactorily improved. On the contrary, according to the present invention, the steps described above are not generated at all, and as a result, the interior and the exterior surfaces of the pipe can be smoothed, thereby obtaining a sufficient fatigue strength. In the present invention, for example, the steps may be eliminated by using an all-in-one type die, or alternatively, the formation of the steps caused by rocking rotation may be prevented by using a fixed die. Of course,

an all-in-one fixed type die may be used for preventing the formation of the steps.

Furthermore, compared to the method in which a die is rocked by using a conventional rotary forging device, since the device structure can be simplified in the present invention, a sufficient load required for processing can be applied, and in addition, sufficient processing can be performed even when a load is increased in the case in which the thickness at the outlet side of the die is formed equivalent to or less than that at the inlet side thereof. Hence, in response to wide requirements of sizes, high dimensional accuracy pipes having a sufficient fatigue strength can be obtained.

In the past, as a method for decreasing the deviations of the outer diameter, inner diameter, and thickness in the circumferential direction to 3% or less, a method by machining (process including removal of parts of materials) has been known; however, the process cost was considerably increased, the process efficiency was inferior, and a long metal pipe having a small diameter was difficult to be processed. Hence, it has been difficult to apply the method described above to automobile parts such as a drive shaft.

As a method for discriminating the above metal pipe processed by machining from this metal pipe (as-processed metal pipe obtained by the push-to-pass of the present

invention), a method for observing the surface of the pipe may be mentioned by way of example, and by this method, the discrimination can be made. The reason for this is that a black skin adheres to the surface of this metal pipe, which skin is generated in pre-steps, such as heating and rolling, for the manufacturing, and on the contrary, on the surface of the pipe formed by machining, a black skin is not present since it was removed thereby.

Furthermore, in terms of thickness deviation, this metal pipe is outstandingly superior to that manufactured by the conventional method (for example, see Patent Documents 1, 2, and 3) by a process of pressing a pipe in a die using a rotary forging device. That is, in the past, a metal pipe as processed by push-to-pass has not been obtained in which at least one of the deviations of the outer diameter, inner diameter, and thickness in the circumferential direction is 3% or less.

In the present invention, the deviations of the outer diameter, inner diameter, and thickness in the circumferential direction are obtained as follows.

The deviation of the outer diameter (or inner diameter) is calculated as the maximum deviation with respect to a target outer diameter (or target inner diameter) from the distribution data of the outer diameter (or inner diameter) in the circumferential direction measured by rotating a pipe

while a micrometer is being in contact with the exterior surface (or interior surface) thereof. Alternatively, from the distribution data in the circumferential direction of the distance between a laser generator and a measured pipe, the exterior surface (or interior surface) of which is irradiated with laser light, the deviation is calculated as the maximum deviation with respect to the target outer diameter (or target inner diameter). In addition, by performing image analysis of a cross-section of the pipe in the circumferential direction, the deviation from a perfect circle is calculated in the circumferential direction, so that the deviation of the outer diameter (inner diameter) may be obtained.

The deviation of the thickness in the circumferential direction is calculated as the difference between the distribution data of the outer diameter in the circumferential direction and that of the inner diameter in the circumferential direction, or is directly measured as the maximum deviation with respect to the target thickness from an image of the cross-section of the thickness obtained by an image analysis of the cross-section of the pipe in the circumferential direction.

In addition, the measurement is performed at optional places with intervals of 10 mm or less except for areas 150 mm from the front and back ends of the pipe, and the

deviation is obtained from values measured at 10 places or more.

That is, the deviations of the outer diameter, inner diameter, and thickness (= deviation of the thickness in the circumferential direction) are defined as follows.

Deviation of outer diameter: (maximum outer diameter - minimum outer diameter)/target outer diameter (or average outer diameter) × 100 (%)

Deviation of inner diameter: (maximum inner diameter - minimum inner diameter)/target inner diameter (or average inner diameter) × 100 (%)

Deviation of thickness: (maximum thickness - minimum thickness)/target thickness (or average thickness) × 100 (%)

Since being a metal pipe in which at least one of the three dimensional accuracy indexes is 3.0% or less, the high dimensional accuracy pipe of the present invention can be used as a metal pipe for drive train parts for automobile required to have a high dimensional accuracy of 3.0% or less.

In addition, in the conventional rotary press forging method shown in Figs. 3A and 3B, since a die 4 is composed of segmented parts and is rocked 12 while it is being used, due to steps formed by the die segmentation, or non-uniform deformation under high stress conditions caused by difference in rigidity of the die in the circumferential direction, the deviation of the thickness in the

circumferential direction cannot be satisfactorily improved.

Compared to the case described above, according to the push-to-pass of the present invention, since the die is an all-in-one type die and is not necessary to be rocked, non-uniform deformation is not generated, and as a result, the interior and the exterior surfaces of the pipe can be smoothed.

Furthermore, in the conventional rotary press forging method, since the pipe 5 must be fed cooperatively with the rock 12 of the die 4, a rocking speed cannot be increased more than a predetermined value due to an impact load limit of the die, and hence the process efficiency is low. In addition, in the conventional drawing, since it has been necessary to strongly hold the front end of the pipe and to apply a tensile force thereto, the pipe must be drawn after the front end of the pipe is narrowed; hence, the processing must be performed for one pipe at a time, and as a result, the process efficiency has bee extremely low.

On the other hand, in the present invention, since the push-to-pass is used, and the plug is being floated, by using pipe feeding means 3, a pushing force 15 is applied to the pipe from the inlet side of the die, and pipes can be continuously fed in the die. Hence, compared to the case in the past, a highly efficient process can be performed. In this case, the "continuous feeding" indicates the case in

which one pipe 5 and the following pipe 5 are continuously fed without any interval interposed therebetween as shown in Fig. 1, and a method for moving a pipe member in a pipe traveling direction may be performed in a continuous movement manner or in an intermittent movement manner in which a stop time is decreased as small as possible.

As preferable pipe feeding means 3, for example, there may be mentioned caterpillars 13 (small pieces holding the pipe connected to each other to form an endless track; see Fig. 5) holding the pipe 5 before processing, endless belts 14 (see Fig. 6) holding the pipe 5 before processing, intermittent feeders 15 (see Fig. 7) holding and alternately and intermittently feeding pipes before processing, a press (not shown in the figure) sequentially pushing pipes before processing, and grooved rolls 16 (see Fig. 8) holding the pipe before processing. The pipe feeding means 3 may be formed in combination of at least one of those described above.

The pipe feeding means is most appropriately selected in consideration of the size (diameter, length, and thickness) of the pipe, a force required for performing the push-to-pass of the pipe, a length required for the pipe after the push-to-pass process, and the like, and in addition, it is also important to ensure a necessary push-to-pass force while faults are being prevented which are

caused when the pipe is sandwiched and/or held.

When the pipe before processing is held between grooved rolls, since the push-to-pass force is easily ensured while faults are prevented from being generated on the pipe, it is preferable to use the structure in which two or more grooved rolls are used, and/or the structure in which at least two stands each having a grooved roll are provided.

In addition, when the plug is being floated, although the push-to-pass conditions are varied which complicatedly relate to angles of the die and plug, lubrication conditions of the surfaces of the die and plug, and the like, the plug is always stably present at a position to which a compressive stress is applied, and hence superior dimensional accuracy can be obtained.

In addition, in manufacturing a high dimensional accuracy pipe, when lubrication occurs between the exterior surface of the plug and the interior surface of the pipe and between the interior surface of the die and the exterior surface of the pipe, since faults such as burn marks are not generated on the surface of the pipe in processing, a pipe having superior surface quality can be manufactured. Furthermore, sine the friction force is decreased by the lubrication, a load required for processing can be decreased, process energy can also be decreased, and in addition, the production efficiency is also improved.

Through research on various lubrication methods carried out by the inventors of the present invention, the following method was discovered and was defined as an essential method of the present invention. That is, on one of the interior surface and the exterior surface of the pipe or both of them, lubricant films are formed beforehand, and the push-to-pass is then performed. As a lubricant used for the lubricant film, any one of liquid lubricants, grease-based lubricants, and drying lubricants is preferably used. As the liquid lubricants, for example, there may be mentioned a mineral oil, a synthetic ester, a plant and animal oil, and a mixture containing at least one of the aforementioned lubricants and an additive. As the grease-based lubricants, for example, there may be mentioned a Li-based grease lubricant, a Na-based grease lubricant, and a mixture containing at least one of the aforementioned lubricants and an additive such as molybdenum disulfide. As the drying lubricants, for example, there may be mentioned a polyacrylic resin, epoxy resin, polyvinyl resin, and polyester resin.

In a method for forming a lubricant film using the resin mentioned above, the resin, a liquid containing the resin diluted with a solvent, or an emulsion of the resin is applied to the pipe. Subsequently, drying is preferably performed using a hot wind or by air-drying. As the solvent

for diluting the resin mentioned above, for example, ethers, ketones, aromatic hydrocarbons, linear and branched hydrocarbons may be mentioned. As a dispersion medium for forming the emulsion of the above resin, for example, water, alcohols, and the mixtures thereof may be mentioned.

As a method for more efficiently manufacturing a high dimensional accuracy pipe, an electric-resistance welded steel pipe formed by performing electric welding of an as-hot rolled steel sheet or a seamless steel pipe as heated in a furnace may be processed without removing oxide scales, and by the method described above, the process cost can be decreased.

In the conventional cold drawing method and rotary press forging method, only the diameter reduction is performed. From raw pipes having the same size, only a specific one degree of processing can be obtained, and pipes having the same outer diameter and different degrees of processing can be hardly manufactured. On the other hand, according to the present invention, as shown in Fig. 1, the plug 1 is formed so as to have a pipe expanding portion 1A expanding the pipe 4 and a diameter reducing portion 1B reducing the diameter of the expanded pipe 4 in cooperation with the die 2. Accordingly, by the use of the raw pipes having the same size, pipes having a predetermined size and different degrees of processing can be manufactured. The

reason for this is as follows. Even when the sizes of the raw pipe and the pipe after the push-to-pass process are individually set to predetermined levels, by adjusting the pipe expansion rate at the expanding portion of the plug, the diameter reduction rate by the diameter reducing portion of the plug is inevitably increased or decreased, and as a result, the degrees of processing of the pipes to be obtained are different from each other.

Pipe expansion rate = 1 - D0/D1

Diameter reduction rate = 1 - D2/D1

In the above equations,

D0 indicates the outer diameter of the raw pipe,

D1 indicates the target outer diameter after pipe expansion, and

D2 indicates the target outer diameter after diameter reduction.

In addition, according to the present invention, in order to increase the production efficiency, sequential and continuous feed of pipes is preferably performed. In this case, when the plug is supported from the inlet side or the outlet side of the die, means such as a bar or a wire used for the above support may become an obstruction, and as a result, it becomes difficult to continuously supply pipes. Hence, the plug is preferably floated in the pipe.

In addition, in order to stably perform the push-to-

pass process of the present invention, the plug must be stabilized in processing. That is, the plug must be stabilized not to be deviated from an appropriate position with respect to the die. Research has been made on this point. The plug receives a surface pressure from the pipe by the pipe expansion and the diameter reduction. When the surface pressure at the diameter reduction side is set larger than that at the pipe expansion side, it was found that the stability of the plug can be obtained. As one of methods for increasing the surface pressure at the diameter reduction side than that at the pipe expansion side, as shown in Fig. 9, a corn angle θA of the pipe expanding portion 1A of the plug 1 is effectively set smaller than a corn angle θB of the diameter reducing portion 1B. In this case, the corn angle of the portion of the plug indicates an angle formed between the surface of the plug at that portion and a linear line 17 parallel to the plug central axis set along the pipe traveling direction. In addition, preferably, $\theta A = 0.3$ to $35°$ and $\theta B = 3$ to $45°$ hold. As another method, the diameter reduction rate is preferably set larger than the pipe expansion rate, and for this purpose, the outside diameter of the pipe at the outlet side of the die is effectively set smaller than the outside diameter of the pipe at the inlet side.

In the present invention, since an all-in-one type

fixed die can be used, steps caused by die segmentation and non-uniform deformation in the circumferential direction do not occur at all. As a result, the interior surface and the exterior surface of the pipe can be smoothed. In addition, by the use of the all-in-one fixed type die, a sufficient load can be applied in processing. Although the load is increased when the thickness at the outlet side of the die is set to equal to or smaller than that at the inlet side, processing can be sufficiently performed. As a result, a superior high dimensional accuracy pipe can be obtained. By using raw pipes having the same size, the range of sizes of product pipes which can be manufactured is increased. However, in order to stably perform the push-to-pass process, plugs and dies must be used which satisfy requirements discovered by the inventors of the present invention. The requirements mentioned above are that the angle (: angle of plug diameter-reducing portion) formed between the surface of the diameter reducing portion of the plug and the processing central axis is set to 5 to 40°, the length (:length of plug diameter-reducing portion) of the same portion is set to 5 to 100 mm, and the angle (:angle of die) formed between the interior surface of the hole in the die at the inlet side and the processing central axis is set to 5 to 40°. In addition, more preferably, the length (: plug bearing portion length) of a bearing portion of the plug is

set to 5 to 200 mm. In the case of the plug, the processing central axis is the axis which is perpendicular to the cross-section in the diameter direction of the plug and is allowed to pass through the center of the cross-section described above, and in the case of the die, the processing central axis is the axis which is perpendicular to the cross-section in the diameter direction of the die hole and is allowed to pass through the center of the cross-section described above. In addition, the bearing portion is a cylindrical portion ranging to the minimum diameter part of the diameter reducing portion.

The reasons the plug and the die are defined as described above are as follows.

(Angle of plug diameter-reducing portion: 5 to 40°)

When the angle of the plug diameter-reducing portion is set to less than 5°, the plug may pass through with the material (: pipe) in some cases, and on the other hand, when the angle of the plug diameter-reducing portion is set to more than 40°, the plug and the material clog the die, so that the push-to-pass process may not be carried out in some cases.

(Length of plug diameter-reducing portion: 5 to 100 mm)

When the length of the plug diameter-reducing portion is set to less than 5 mm, the plug may pass through with the material in some cases. On the other hand, when the length

of the plug diameter-reducing portion is set to more than 100 mm, since the friction force between the plug and the material is increased, both of them clog the die, so that the push-to-pass process may not be carried out in some cases.

(Angle of die: 5 to 40°)

When the angle of the die is set to less than 5°, the plug charged in the material may pass through together therewith in some cases, and on the other hand, when the angle of the die is set to more than 40°, the plug and the material clog the die, so that the push-to-pass process may not be carried out in some cases.

(Length of plug bearing portion: 5 to 200 mm)

By a reaction force of the material and the die applied to the diameter reducing portion of the plug, a force is applied to the plug so as to pass it to the inlet side of the die; hence, a force which pushes the plug to the outlet side of the die and which is balanced with the reaction force described above must be applied so as to place the plug in a stable state. For this purposes, the bearing potion is preferably provided for the plug so that a friction force working on the surface thereof is used. According to research by the inventors of the present invention, in order to use this friction force for sufficient stabilization of the plug, the length of the plug

bearing portion is preferably set to 5 to 200 mm. When the length of the plug bearing portion is less than 5 mm, the friction force pushing the plug is insufficient, and by the reaction force of the material and the die, the plug is liable to be pushed back toward the inlet side of the die. On the contrary, when the length of the plug bearing portion is more than 200 mm, since the friction force is excessively large, the plug is liable to be pushed to the outlet side of the die. Hence, in both cases, the position of the plug becomes unstable.

In addition, in the present invention, since the plug is being floated, even when the push-to-pass conditions are varied which complicatedly relate to the angles of the die and plug, the lubrication conditions of the surfaces of the die and plug, and the like, the plug can be placed at a position at which a stable compressive stress state can be obtained. In addition, since the stability of the push-to-pass process can be further improved, it is preferable that the thickness at the outlet side of the die be set to equal to or less than the thickness at the inlet side.

When the push-to-pass process is performed, it may occur in some cases that the pipe is clogged with the plug, and that the load is increased. In the case described above, a raw pipe pushed in may be buckled, and as a result, the process may not be carried out in some cases. Accordingly,

in order to stably perform the push-to-pass process, the buckling of the raw pipe must be prevented beforehand. Hence, the inventors of the present invention focused on the load during the push-to-pass process. That is, when the plug clogs the pipe, the load in the push-to-pass process direction is extremely increased; hence, when this load is not more than a specific value, the push-to-pass process can be performed. When the load is more than the specific value, it is determined that this push-to-pass process cannot be further continued, and in this case, the push-to-pass conditions may be changed to optimum conditions. This specific value is called a push-to-pass load limit.

In the case in which the push-to-pass process cannot be performed, since the raw pipe pushed in the die is buckled, when the push-to-pass load limit is obtained from an equation representing the buckling of the pipe, the stable push-to-pass process can be performed at a load not more than the load limit. As the equation representing the buckling of the pipe, Euler's equation obtained from the elastic modulus of materials has been well known. However, according to the investigation by the inventors of the present invention, values apparently different from those of the actual phenomenon were obtained, and hence, the equation described above cannot be used at all. Accordingly, through research on various equations relating to the buckling, it

was found that the following equation 4 most appropriately represents the actual phenomenon.

[Equation 4] $\sigma_k \times$ cross-sectional area of raw pipe

In the above equation, the following equations hold, and reference labels indicate as follows.

$\sigma_k = YS \times (1-\alpha \times \lambda)$,

$\lambda = (L/\sqrt{n})/k$,

a = 0.00185 to 0.0155,

L: Length of raw pipe,

k: Secondary diameter of cross-section

$k^2 = (d_1{}^2 + d_2{}^2)/16$,

n: Pipe end conditions (n=0.25 to 4),

d_1: Outer diameter of raw pipe,

d_2: Inner diameter of raw pipe, and

YS: Yield strength of raw pipe

In order to stably perform the push-to-pass process, when a load (measured load) measured in the push-to-pass direction is not more than the value (calculated value) of the equation 4, the push-to-pass process may be continued. When the measured load exceeds the above value, after the process is once stopped, the conditions are changed, and the process may be again started.

However, since the equation 4 is relatively complicated, when it is desired that the determination be more easily made, the following equation 5 which is obtained by

simplifying the equation 4 may be used.

[Equation 5] Yield strength YS of raw pipe × cross-sectional area of raw pipe

By the equation 5, although the push-to-pass load limit is increased by up to approximately 10 percent as compared to that by the equation 4, the inventors of the present invention understood that sufficient determination can be simply made by the value thus obtained.

In addition, when a raw pipe having an extremely short length (such as a length of approximately 0.2 m or less) is processed by the push-to-pass, or when the process is forcedly performed in a very short period of time in which even when the pipe is buckled to a certain extent, the load is increased by increasing the processing speed to a level at which the die may not be cracked, the following equation 6 may also be used.

[Equation 6] Tensile strength TS of raw pipe × cross-sectional area of raw pipe

In the case described above, as a measurement method of the measured load (actual load in the push-to-pass direction), for example, a method using a load cell provided at a punch of the push-to-pass, or a method using a load cell integrated with a die which is floated from a platform is preferably used.

When the measured load exceeds the calculated load

obtained by using one of the equations 4 to 6, that is, when the execution of the process is regarded as impossible, the push-to-pass process is temporarily stopped, and after the die and/or the plug is exchanged to that having a different shape and being in conformity with the same product pipe dimension, the process may be restarted. In the case described above, since the die and/or the plug having a different shape in conformity with the same product pipe dimension is used for processing raw pipes identical to that used before, selection may be performed from that having the same diameter reduction rate.

In addition, in order to obtain more stable process conditions, according to research carried out by the inventors of the present invention, it was found that the angles (see Fig. 10) of the plug and die to be used after the exchange are preferably smaller that that of those used before the exchange.

In order to obtain even more stable process conditions, the type of lubricant applied to the raw pipe may be changed. However, when a method is performed in view of convenience in which a lubricant is applied by immersing a raw pipe into a coating bath containing a lubricant, for example, since the exchange of the lubricant may take a lot of time, it is difficult to frequently change the type of lubricant. Hence, as for the lubricant, it is important that, by experiments

performed beforehand, a material be selected which has properties capable of significantly decreasing the load in the push-to-pass direction.

Compared to the case described above, in the case of the push-to-pass of the present invention, as shown in Fig. 1, the plug 1 is charged in the pipe 4, and the pipe 4 is pushed in the hole provided in the die 2 and is then allowed to pass therethrough. In this step, the plug can be in contact with the entire circumference of the interior surface of the pipe in the processing tool and the hole can be in contact with the entire circumference of the exterior surface of the pipe in the processing tool. By a pushing force 11 applied at the inlet side of the die 2, a compressive force works entirely inside the processing tool. As a result, at both the inlet and outlet sides of the processing tool, the pipe 4 can be sufficiently brought into contact with the plug 1 and die 2. In addition, even at a small diameter reduction rate, since the compressive strength is generated inside the processing tool, compared to the drawing, the contact between the pipe and the plug and that between the pipe and the die are likely to be sufficiently made. Hence, the pipe is likely to be smoothed, and as a result, a high dimensional accuracy pipe can be obtained. In addition, in the case of the push-to-pass, smoothing of the interior and the exterior surfaces of the

pipe can be performed even at a small diameter reduction rate, and the processing strain is small as compared to that of the drawing; hence, a load of heat treatment performed after the diameter reduction is small, or the heat treatment may be omitted, and as a result, the manufacturing cost is decreased.

Hence, the structure of the apparatus of the present invention has the plug 1 contactable with the entire circumference of the interior surface of the metal pipe 4, the die 2 having the hole contactable with the entire circumference of the exterior surface of the metal pipe 4, and a pipe pushing device 3 pushing the metal pipe 4, and the push-to-pass can be performed in which, while the plug 1 is being charged in the pipe, the metal pipe 4 is pushed in the hole provided in the die 2 by the pipe pushing device 3 and is then allowed to pass therethrough.

In addition, in a pressing process using the conventional rotary forging device 8 shown in Fig. 3, since the segmented die 9 formed by dividing an all-in-one type die in the circumferential direction is used, and in addition, the segmented die 9 is rocked 12, steps are formed due to the segmentation, or non-uniform deformation is generated under high stress conditions due to the difference in rigidity of the die in the circumferential direction, the accuracy of the thickness cannot be satisfactorily improved.

On the contrary, according to the apparatus formed to be capable of performing the push-to-pass of the present invention, since the metal pipe is allowed to pass through the hole provided in the die, which hole can be in contact with the entire circumference of the exterior surface of the pipe in the same cross-section, the steps formed by the use of the segmented die are not generated at all, and as a result, smoothing of the interior and the exterior surfaces of the pipe can be performed.

Furthermore, in the present invention, as the die, an all-in-one type die is used. Compared to the conventional method using a segmented die fitted to a rotary forging device, the structure of the apparatus can be simplified. A sufficient load required for processing can be applied, and even when the load is increased since the thickness at the outlet side of the die is formed equivalent to or less than that at the inlet side, sufficient processing can be performed. Hence, in response to wide requirements of sizes, pipes having significantly superior dimensional accuracy can be obtained.

In addition, according to the present invention, the plug is being floated. Even when the push-to-pass conditions, such as angles of the die and plug, lubrication of the surfaces of the die and plug, and the like, are complicatedly varied, the plug is always stably located at a

position at which the compressive stress is applied. Hence, superior dimensional accuracy can be stably obtained.

Furthermore, in the conventional drawing, since the front end of the pipe must be narrowed so as to be drawn, the process must be performed for one pipe at a time. On the other hand, according to the present invention, it is not necessary to narrow the front end of the pipe, and pipes themselves can be sequentially pushed. When the plug is being floated, the push-to-pass can be continuously performed, and hence the productivity is significantly improved. In addition, when the length of the pipe is small, by using a device performing intermittent pushing operation as the pipe pushing device, high dimensional accuracy pipes can be manufactured while a high productivity is being maintained. In this case, the pipe pushing device may hold a body portion of the pipe and push it or may push one end of the pipe.

Pipes which must be processed by the push-to-pass have widely diverse product dimensions. In the push-to-pass, in order to change the outer diameters of products, dies having different hole sizes are prepare and must be exchanged whenever the outer diameter of a product is changed. In addition, the hole dimension of the die is generally represented by the diameter, angle, and length of a tapered portion.

Since the dimensions of the outer diameters among products are finely different from lot to lot by a several-ton unit at minimum, at each change in dimension, a die which has been used must be removed, and a die to be used must be fitted; however, the die-fitting accuracy is very severe, such as ± 0.1 mm units, and hence considerable time and labor have been required.

For reducing the time and labor required for the die exchange, the inventors of the present invention found the solution. That is, the solution is that dies having various hole sizes in conformity with the outer diameters of products are prepared, are arranged in a predetermined manner, and are then exchanged sequentially.

In a method for manufacturing a high dimensional accuracy pipe by the push-to-pass in which a plug is charged in pipes and is being floated, and the pipes are continuously or intermittently pushed in a die, a plurality of dies having different hole sizes is arranged in the same circumference. A die having a hole size in conformity with a target product dimension is only rotated in the circumferential direction of the arrangement to be disposed in a pass line for performing the push-to-pass. When the product dimension of the following pipe is different from that of the preceding pipe, in the same manner as described above, a die having a hole size in conformity with the outer

diameter dimension of the following pipe may also be rotated so as to be disposed in the pass line for performing the push-to-pass.

As one example, as shown in Fig. 11, the die 2 through which the pipe 4 is allowed to pass, a pushing device 2 pushing the pipe 4 in the die 2 placed in the pass line, and a plurality of dies 2, 20,---, 20 disposed in the same circumference are supported and moved in the circumferential direction. When an apparatus having a die rotating platform 19 which disposes one of the dies 2 in the pass line is used, the process can be easily performed.

In addition, as another example, a plurality of dies having different hole sizes is arranged on the same liner line, one of the dies in conformity with the product dimension may be moved in the linear line direction of the arrangement so as to be disposed in the pass line for performing the push-to-pass.

In the case described above, for example, as shown in Fig. 12, the die 2 through which the pipe is allowed to pass, the pushing device 2 pushing the pipe 4 in a die 3 placed in the pass line, and a plurality of dies 2, 20,---, 20 disposed on the same linear line are supported and moved in the linear line direction. When an apparatus having a die linear-driving platform 23 which disposes one of the dies 2 in the pass line is used, the process can be easily

performed.

Furthermore, the charge of the plug must also be efficiently performed. When the plug can be easily exchanged while the die is being exchanged, the efficiency is further improved. Since remaining in the die, the plug 1 used for the preceding process is removed at the same time when the die is exchanged. A plug 22 necessary for the following step is preferably charged in the pipe during the exchange of the die.

For the purpose described above, in one of the first and the second methods of the present invention, when the production dimension for the preceding pipe is changed to that for the following pipe, after the push-to-pass is completed for the preceding pipe, the following pipe is stopped at the inlet side of the die. Before or after a die in conformity with the production dimension for the following pipe is moved or during the movement thereof, the plug 22 in conformity with the above production dimension is preferably charged in the following pipe. Accordingly, in addition to the die, the plug can also be efficiently exchanged.

When the push-to-pass process is performed, the pipe at the outlet side of the die is liable to be bent. When being bent, the pipe cannot be formed into a product, and hence a technique for performing the process without bending pipes

is required. In the conventional drawing, since the process is performed while a tension is applied to each pipe by holding the front end thereof at the outlet side of the die, although the process efficiency is low, the pipe is unlikely to be bent since being guided in the drawing direction. However, in the push-to-pass, the movement of the pipe at the outlet side of the die is free, and depending on the forming accuracy of the die, thickness accuracy and surface conditions of a pipe before processing, and non-uniform lubrication states of the die and plug, the pipe is liable to be bent. Hence, a technique preventing the pipe from being bent at the outlet side of the die has been seriously desired.

Accordingly, the inventors of the present invention carried out experiments on bending of the pipe after the push-to-pass. In the experiments, the pipe is guided through guide tubes provided at the inlet and the outlet sides of the die. When the guide tube is provided at one of the inlet and the outlet sides of the die, the pipe becomes unlikely to be bent, when the tubes are provided at both sides, the pipe becomes more unlikely to be bent, and when the position of the guide tube is provided closer to the outlet of the die, the pipe becomes more unlikely to be bent.

Accordingly, the guide tubes may be provided at the inlet side of the die and at a position very close to the

outlet side of the die. That is, the guide tube is preferably provided at the outlet side of the die and at a position very close thereto. However, it was found that, depending on the bending direction of the pipe, the bending cannot be sufficiently prevented in some cases. In order to prevent the bending regardless of the bending direction of the pipe, the space between the exterior surface of the pipe and the interior surface of the guide tube must be decreased to substantially zero. However, in the case described above, it was found that since the pipe and the guide tube are too much brought into contact with each other, problems occur in that faults are generated, a push-to-pass force is extremely increased, and the like.

The inventors of the present invention understood that bending of the pipe starts even at a position which is very close to the outlet side of the die. That is, depending on the forming accuracy of the die, thickness accuracy and surface conditions of a pipe before processing, and non-uniform lubrication states of the die and plug, a residual stress is generated in the pipe, and since this residual stress is rapidly released at a position which is very close to the outlet side of the die, the bending is liable to occur. Hence, when fine adjustment means for adjusting the bending direction of the pipe is provided at a position which is very close to the outlet side of the die, the

bending of the pipe can be sufficiently prevented.

Through intensive research carried out by the inventors of the present invention, at a position which is very close to the outlet side of the die, fine adjustment means for adjusting pipe bending is provided which has a hole body allowing the pipe to pass therethrough, a support substrate supporting the hole body so as to enable it to move in the plane perpendicular to the pipe traveling direction, and a hole body-moving mechanism which is supported by the support substrate and which moves the hole body. It was understood that when the pipe at the outlet side of the die is allowed to pass through the hole body, which is finely moved beforehand in the plane of the support substrate by fine adjustment of the hole body-moving mechanism so as to be placed at a position in the plane perpendicular to the pipe traveling direction, pipe bending can be sufficiently prevented.

For finely adjusting the position of the hole body, for example, by using a plurality of dummy pipes is used before actual production is performed, a push-to-pass process experiment is performed in which the hole body position is changed several times so that the pipe bending is measured, and the relationship between the change amount of the position of the hole body and that of the pipe bending after the push-to-pass is obtained. A method is preferably used

in which when the pipe bending in actual production is about to exceed a predetermined threshold, the hole body is moved to the direction so as to decrease the bending based on the relationship described above.

As the hole body-moving mechanism, for example, a method is preferably used in which at least one place of the peripheral portion of the hole body is pushed in the direction perpendicular to the pipe traveling direction through a tapered surface of a wedge-shaped mold, the tapered surface being designed to be moved in the pipe traveling direction by using a screw. Alternatively, for example, a method is preferably used in which at least one place of the peripheral portion of the hole body is directly pushed or pulled in the direction perpendicular to the pipe traveling direction using a fluid pressure cylinder (such as hydraulic cylinder or air cylinder).

When the hole size of the hole body is formed larger than the hole size of the outlet of the die, it is preferable since the pipe is not blocked at the outlet side of the die, and the process can be smoothly performed. In particular, when the hole size is larger than that of the outlet of the die by +0 to +3 mm, it is more preferable since fine adjustment can be easily performed. In this case, the hole provided in the hole body may be either a straight hole or a tapered hole.

Of course, in the support substrate, a hollow portion through which the pipe is allowed to pass with a sufficient space therebetween is provided at a position intersecting a path of the pipe passing through the die.

In addition, at the inlet side of the die and/or an outlet side of the fine adjustment means for adjusting pipe bending, when a guide tube through which the pipe about to enter the die is allowed to pass and/or a guide tube through which the pipe passing through the fine adjustment means for adjusting pipe bending is allowed to pass is provided, the pipe enters the die approximately perpendicularly thereto and/or passes through the fine adjustment means for adjusting pipe bending approximately perpendicularly thereto, and it is preferable since the bending of the pipe can be more easily prevented.

In addition, in the present invention, it is preferable that pipes be continuously fed and pushed in the die. By continuously feeding the pipes, compared to the case in which processing is performed for one pipe at a time, heat generated by friction and that generated by processing, which are applied to the die and plug, are stabilized, and hence the bending can be more easily prevented. In the push-to-pass, unlike the drawing, since a metal pointing process is not required which enables a drawing device provided at the outlet side of the die to hold the front end

of the pipe, pipes can be continuously fed by pushing the back end of the preceding pipe with the front end of the following pipe, and hence the production efficiency can be improved.

In the conventional drawing, a sufficient lubricant film is necessary in order to obtain high dimensional accuracy, and hence bonderizing treatment having superior lubrication has been performed. A method therefor is performed by the steps of removing oxide scales from a pipe by pickling, performing alkaline washing for neutralization of an acid used in the above treatment, and then performing water washing. Subsequently, the pipe is immersed in a bath in which the bonderizing treatment is performed to form a lubricant film, and is then immersed in a bath containing metal soap to form a film, followed by drying of the pipe with a hot wind. Accordingly, the steps described above take several hours or more, and when the steps are incorporated in a manufacturing line which performs drawing of pipes, the productivity is extremely decreased; hence, the treatment has been performed in a different process.

Compared to the case described above, according to the push-to-pass process, even when the diameter reduction rate is small, since high dimensional accuracy can be easily obtained, the lubrication treatment of the pipe may be simply performed. That is, the pipe may not be processed by

pickling and may be simply dried with a hot wind after coating of a lubricant is performed by immersion. However, when the push-to-pass is continuously performed, since the perpendicularity of the end surface of the pipe is important, a grinding device for obtaining this perpendicularity must be provided.

These treatment performed before the push-to-pass process are most efficiently carried out when the steps of obtaining the perpendicularly of the end surface of the pipe, applying the lubricant thereto by immersion, and drying are performed in that order. In the present invention, from the above point of view, since a manufacturing line is formed in which a pipe end-grinding device grinding the end surface of the pipe perpendicularly with respect to the pipe axis direction, a lubricant immersion coating bath for applying a lubricant to pipes by immersion, and a drying device drying the pipes coated with the lubricant are provided in that order at an inlet side of the push-to-pass device, high dimensional accuracy pipes can be efficiently manufactured.

In addition, since the step of obtaining the perpendicularly of the end surface of the pipe is more efficiently performed right after the pipe is cut into short ones, in the manufacturing line of the present invention, a cutting device cutting the pipe into short ones is preferably provided at the inlet side of the pipe end-

grinding device.

In addition, as the lubricant, when a material which easily forms a film by drying is used, instead of performing coating by immersion at the inlet side of the push-to-pass device, followed by drying, spray coating may be performed at a position very close to the inlet side of the die in the push-to-pass process device, followed by drying, or when lubricant properties are more superior, by omitting the drying, the push-to-pass process may be performed for a pipe coated with a lubricant which is still being in a wet state. Hence, in the manufacturing line of the present invention, instead of the lubricant immersion coating bath and the drying device, there may be provided, at the inlet side of the die of the push-to-pass device, a spray coating device spraying a lubricant to the pipe or a lubricant spray coating and drying device for coating the pipe with a lubricant, followed by drying.

In addition, in order to further improve the efficiently of the push-to-pass process, it is preferable that the die and plug be easily exchanged on-line, and that the pipe be controlled so as not be bent at the outlet side of the die. In consideration of the points described above, in the manufacturing line of the present invention, in addition to the push-to-pass device, there is preferably provided at least one of a die exchange device for

exchanging the die, a plug exchange device for exchanging the plug, a bending prevention device for preventing the bending of the pipe at the outlet side of the de.

The die (or plug) exchange device preferably has the structure in that dies (or plugs) having different dimensions (and/or shapes) are arranged in the order in which they are to be used and are then sequentially moved to a predetermined place in a pipe traveling line. The bending prevention device preferably has the structure in that, for example, by using a movable disc or the like having a hole through which the pipe is allowed to pass, a force may be applied to a pipe at a place very close to the outlet side of the die in the direction opposite to that in which the pipe is about to be bent.

In addition, in both the drawing conventionally used and the push-to-pass of the present invention, since pipes having a surface processed by pickling may be frequently required after the above process is completed, shipment is preferably carried out after pickling is performed in a different process. In the drawing, when the bonderizing treatment is performed before the process is carried out, in order to form a strong film of a lubricant, raw pipes must be processed by pickling, and after the drawing, pickling must again be performed for removing the lubricant; hence, pickling must be performed twice. Compared to the case

described above, in the push-to-pass process, simple lubrication treatment may be performed before processing, and oxide scales may still adhere to raw pipes. Hence, after being designed to be operated on-line, the lubrication treatment can be incorporated in the manufacturing line, and as a result, an efficient manufacturing line can be realized at a reasonable cost.

Example 1

Hereinafter, the present invention will be described in detail with reference to examples.

In Example 1.1, a push-to-pass process having the structure shown in Fig. 1 was performed for a steel pipe having an outer diameter of 40 mm and a thickness of 6 mm. In this case, a plug having a mirror surface which was to be brought into contact with the interior surface of the pipe and a die which was an all-one-in fixed die and has a mirror surface to be brought into contact with the exterior surface of the pipe were used. The plug was fixed at one end and was charged in the pipe. The process conditions were set so that the thickness at the outlet side was made equal to that at the inlet side, and the diameter reduction rate was set to 10%.

In Example 1.2, the process was performed in the same manner as that in Example 1.1 except that the diameter

reduction rate was set to 5%.

In Example 1.3, the process was performed in the same manner as that in Example 1.2 except that the plug was being floated.

In addition, as Comparative Example 1.1, the process was performed in the same manner as that in Example 1.2 except that the drawing was performed having the structure shown in Fig. 2 instead of the push-to-pass having the structure shown in Fig. 1, and that the thickness at the outlet side was set smaller than that at the inlet side.

In addition, as 1.2, the process was performed in the same manner as that in Example 1.2 except that instead of the all-in-one fixed type die, a segmented die was incorporated in a rotary forging device having the structure shown in Fig. 3 and was rocked, and that instead of the push-to-pass process, a pressing process was performed.

In addition, as Comparative Example 1.3, the process was performed in the same manner as that in Comparative Example 1.2 except that the process conditions were changed so that the thickness at the outlet side was set to equal to the thickness at the inlet side + 1 mm (= 7 mm).

The three dimensional accuracy indexes of the above steel pipes processed by diameter reduction were obtained, and the steel pipes were subjected to a fatigue test. The results are shown in Table 1.

In this case, the deviations of the outer and the inner diameters shown in Table 1 were obtained by the measurement using laser light described above, and from the difference in distribution of the measured data in the circumferential direction, the deviation of the thickness in the circumferential direction was obtained, which is also shown in the same table as described above.

In addition, a test for obtaining the number of repeated cycles (that is, endurance cycles) until cracking is generated at a constant stress is performed, and in Fig. 4, the relationship between the number of endurance cycles and stress levels which are variously changed is shown. In this figure, the number of cycles until an endurance limit shown in Table 1 represent the number of endurance cycles at an elbow point at which the stress in a decreasing state is about to reach an approximately constant value as the number of the endurance cycles is increased, and the fatigue strength is more superior as the value described above is increased. That is, in this example, the number of the endurance cycles was at a stress of approximately 150 MPa.

As can be seen from Table 1, the pipe products of Examples 1.1 to 1.3 had significantly superior dimensional accuracy and the most superior fatigue strength, and when the plug was being floated, the dimensional accuracy was further improved (Example 1.3). On the other hand, in the

conventional drawing, the dimensional accuracy of the pipe product was degraded, and as a result, the fatigue strength was also extremely decreased (Comparative Example 1.1). In the pressing process by using the rotary forging device, the dimensional accuracy of the pipe product was degraded (Comparative Example 1.2), and when the thickness is increased, the dimensional accuracy was further degraded (Comparative Example 1.3); hence, a sufficient fatigue strength could not be obtained.

Example 2

As one example of the present invention, the push-to-pass process was carried out in which a steel pipe 40 mm in diameter, 6 mm thick, and 5.5 m long was used as a raw material, a plug having a mirror surface and an all-in-one fixed type die were used, the plug was floated and charged in the steel pipe, the steel pipe was pushed from the inlet side of the die at a diameter reduction rate of 5%, and the thickness of the steel pipe at the outlet side of the die was set to 6 mm which was equivalent to that at the inlet side of the die. In this example, as pipe feeding means, intermittent feeding device having the structure shown in Fig. 7 was used so that the pipes were continuously fed in the die.

In addition, as Comparative Example 2.1, drawing having the structure shown in Fig. 2 was performed. In this

example, the same steel pipe as described above was used a raw material, the same plug and die were used as above, the plug was charged in the steel pipe, the steel pipe was drawn from the outlet side of the die at the same diameter reduction rate as above, and the thickness of the steel pipe at the outlet side of the die was decreased to 5.5 mm.

In addition, as Comparative Example 2.2, a rotary press forging method having the structure shown in Figs. 3A and 3B was performed. In this example, the same steel pipe as described above was used as a raw material, a rotary forging device was employed which used a segmented die instead of the above all-in-one fixed type die, the same plug as above was charged in the steel pipe, the rotary press forging was performed at the same diameter reduction rate as above, and the thickness of the steel pipe at the outlet side of the forging device was increased to 7 mm.

The dimensional accuracy (deviation of the outer diameter, deviation of the inner diameter, and deviation of the thickness in the circumferential direction) of the steel pipes manufactured by the methods of the above individual examples was measured, and the process efficiency was also investigated. The results are shown in Table 2. The deviation of the outer diameter and that of the inner diameter were obtained by performing image analysis of the cross-section of the pipe in the circumferential direction,

followed by calculation of the deviation from a perfect circle in the circumferential direction. In addition, image analysis of the cross-section of the pipe in the circumferential direction was performed, and the deviation of the thickness in the circumferential direction was directly measured as the maximum deviation with respect to the average thickness from the image of the cross-section of the thickness.

As can be seen from Table 2, the steel pipes manufactured by the push-to-pass of the examples of the present invention had significantly superior dimensional accuracy and also had superior process efficiency. On the other hand, the steel pipe manufactured by the drawing of Comparative Example 2.1 had degraded dimensional accuracy. In addition, the steel pipe manufactured by the rotary press forging of Comparative Example 2.2 also had degraded dimensional accuracy. In addition, in both the drawing and the rotary press forging, the process efficiency was very low.

Example 3

[Comparative Example 3.1] An electric-resistance welded pipe 40 mm in diameter, 6.0 mm thick, and 5.5 m long having scales on the surface thereof caused by hot rolling was processed by the push-to-pass shown in Fig. 1 under the following conditions A.

(Conditions A) Plug: a plug having a mirror surface being charged in the pipe and being floated.

Die: an all-in-one fixed type die

Diameter reduction rate: 5%

Thickness of the pipe at the outlet side of the die: 6.0 mm (= the thickness at the inlet side)

[Example of present invention 3.1] Lubricant films were formed by applying a liquid lubricant (mineral oil) onto the interior and exterior surfaces of the same pipe as described above, and subsequently, the process was performed in the same manner as that in Comparative Example 3.1.

[Example of present invention 3.2] Lubricant films were formed by applying a grease-based lubricant (lubricant composed of a Li-based grease lubricant and molybdenum disulfide added thereto) onto the interior and exterior surfaces of the same pipe as described above, and subsequently, the process was performed in the same manner as that in Comparative Example 3.1.

[Example of present invention 3.3] Lubricant films were formed by applying a drying lubricant (polyalkyl-based lubricant) onto the interior and exterior surfaces of the same pipe as described above, followed by drying with a hot wind (approximately 200°C), and subsequently, the process was performed in the same manner as that in Comparative Example 3.1.

[Example of present invention 3.4] Lubricant films were formed by applying a liquid obtained by diluting a drying lubricant (polyalkyl-based lubricant) with a solvent (acetone) onto the interior and exterior surfaces of the same pipe as described above, followed by drying with a hot wind (approximately 50°C), and subsequently, the process was performed in the same manner as that in Comparative Example 3.1.

[Example of present invention 3.5] Lubricant films were formed by applying an emulsion obtained by dispersing a drying lubricant (polyalkyl-based lubricant) in a dispersion medium (water) onto the interior and exterior surfaces of the same pipe as described above, followed by drying with a hot wind (approximately 70°C), and subsequently, the process was performed in the same manner as that in Comparative Example 3.1.

[Comparative Example 3.2] Lubricant films were formed by applying the same liquid lubricant as that of Example 1 of the present invention onto the interior and exterior surfaces of the same pipe as described above, and subsequently, the process was performed by the cold drawing method shown in Fig. 2 under the following conditions B.

(Conditions B) Plug, die, diameter reduction rate: the same as those of the conditions A

Thickness of the pipe at the outlet side of

the die: 5.5 mm (< the thickness at the inlet side)

[Comparative Example 3.3] Lubricant films were formed by applying the same liquid lubricant as that of Example 1 of the present invention onto the interior and exterior surfaces of the same pipe as described above, and subsequently, the process was performed using the rotary press forging method shown in Fig. 3 under the following conditions C.

(Conditions C) Plug: the same as that of the conditions A

Die: a segmented die

Diameter reduction rate: the same as that of the conditions A

Thickness of the pipe at the outlet side of the die: 7.0 mm (> the thickness at the inlet side)

Surface fault conditions and dimensional accuracy (deviation of the outer diameter, deviation of the inner diameter, and deviation of the thickness) were measured for the steel pipes manufactured by the methods of the above individual examples, and the results are shown in Table 3. The deviation of the outer diameter and that of the inner diameter were obtained by performing image analysis of the cross-section of the pipe in the circumferential direction, and then calculating the maximum deviation (that is, (maximum diameter - minimum diameter)/diameter of the perfect circle × 100%)) deviated from the perfect circle in

the circumferential direction. In addition, the deviation of the thickness in the circumferential direction was obtained by performing image analysis of the cross-section of the pipe in the circumferential direction, and directly measuring the maximum deviation (that is, (maximum thickness - minimum thickness)/average thickness × 100%)) with respect to the average thickness from the image of the cross-section of the thickness.

As can be seen from Table 3, in all the examples of the present invention in which the push-to-pass was performed under the lubrication conditions, faults were not generated at all on the surface of the steel pipe after the process, superior surface quality was obtained, and the dimensional accuracy was also significantly superior. On the contrary, in Comparative Example 3.1 in which the push-to-pass was performed under non-lubrication conditions, faults were generated on the surface of the steel pipe after the process. In Comparative Example 3.2 in which the process was performed by the cold drawing method under the lubrication conditions, the dimensional accuracy was degraded. In Comparative Example 3.3 in which the rotary press forging was performed under the lubrication conditions, the dimensional accuracy was further degraded.

In the examples of the present invention described above, the case of so-called double-sided lubrication was

shown in which the lubrication films were formed on the interior and the exterior surfaces of the pipe; however, the present invention is not limited thereto, and the case in which a lubricant film is formed on one of the interior and the exterior surfaces of the pipe may also be included. In the case of this one-sided lubrication, it is apparent that the generation of faults on the surface on which the lubrication film is formed can be effectively prevented.

Example 4

[Example of present invention]

After steel pipes 40 mm in diameter, 6 mm thick, and 5.5 m long was prepared as raw pipes, pipe expansion and diameter reduction of this raw pipe were sequentially performed by the process (push-to-pass using a plug capable of performing pipe expansion and diameter reduction) of the present invention, the brief structure of the process being shown in Fig. 1. A target thickness at the outlet side of the die was set to 6.0 mm which was the same as that at the inlet side. A plug having a mirror surface was floated in the pipe. An all-in-one fixed type die was used as the die in which the interior surface of the die hole was mirror finished. The pipe expansion rate, diameter reduction rate, corn angles θA and θB of the pipe expanding portion and the diameter reducing portion, respectively, and a target outer diameter D2 of the pipe at the outer side (after diameter

reduction) of the die of each example were set to the values shown in Table 4. The pipes were continuously fed to the die.

[Comparative Example A]

By the cold drawing method (: only diameter reduction could be performed) shown in Fig. 2, the diameter reduction of the same raw pipe as described above was performed. The target thickness at the outlet side of the die was set to 6.0 mm which was the same as that at the inlet side. A mirror finished plug was floated in the pipe. An all-in-one fixed type die was used as the die in which the interior surface of the die hole was mirror finished. The diameter reduction rate and the target outer diameter of the pipe at the outer side of the die of each example were set to the values shown in Table 4. The pipes were continuously fed to the die.

[Comparative Example B]

By the rotary press forging method (: only diameter reduction could be performed) shown in Fig. 3, the diameter reduction of the same raw pipe as described above was performed. The target thickness at the outlet side of the die was set to 6.0 mm which was the same as that at the inlet side. A mirror finished plug was floated in the pipe. A segmented die was used as the die in which the interior surface of the die hole was mirror finished. The reduction

rate and the target outer diameter of the pipe at the outer side of the die of each example were set to the values shown in Table 4. The pipes were continuously fed to the die.

The dimensional accuracy (deviation of the outer diameter, deviation of the inner diameter, and deviation of the thickness) of the steel pipes manufactured by the methods of the above individual examples was measured. The deviation of the outer diameter and that of the inner diameter were obtained by performing image analysis of the cross-section of the pipe in the circumferential direction, and then calculating the maximum deviation (that is, (maximum diameter - minimum diameter)/diameter of the perfect circle × 100%)) deviated from the perfect circle in the circumferential direction. In addition, the deviation of the thickness in the circumferential direction was obtained by performing image analysis of the cross-section of the pipe in the circumferential direction, and directly measuring the maximum deviation (that is, (maximum thickness - minimum thickness)/average thickness × 100%)) with respect to the average thickness from the image of the cross-section of the thickness. In addition, as the index of the degree of processing, cross-sectional hardness was measured. In addition, as the index for determining whether a pipe having a predetermined size is obtained after processing or not, the average outer diameter and the average thickness of the

pipe after processing were used, which were simultaneously obtained when the measurement of the above dimensional accuracy was performed. The results are shown in Table 4.

As can be seen from Table 4, all the examples according to the present invention had significantly superior dimensional accuracy after processing, and when the combination of the plug and the die was changed, from raw pipes having the same size, pipes having a predetermined size and having different degrees of processing could be obtained. On the contrary, in the comparative examples, the dimensional accuracy was degraded, and, in order to obtain pipes having different degrees of processing from raw pipes having the same size, pipes having a predetermined outer diameter or thicknesses could not be obtained. In the example of the present invention in which at least one of $\theta A < \theta B$ and $D2 < D0$ was satisfied, the floating state of the plug in the pipe was further stabilized.

In addition, the individual rates are defined as follows.

$$\text{Pipe expansion rate a (\%)} = (D1 - D0)/D1 \times 100$$

$$\text{Diameter reduction rate b (\%)} = (D1 - D2)/D1 \times 100$$

Example 5

(Examples 5.1 to 5.4)

After electric-resistance welded steel pipes 40 mm in outer diameter and 6 mm thick were prepared as raw pipes,

the raw pipe was experimentally processed by the push-to-pass process shown in Fig. 1 using a plug having a mirror surface and an all-in-one fixed type die. Shape conditions (angle of plug diameter-reducing portion, length of plug diameter-reducing portion, length of plug bearing portion, and angle of die) of the plugs and the dies used in these examples are shown in Table 5. The plug was floated in the pipe. The thickness of the pipe at the outlet side of the die was set to 5 mm.

(Comparative Examples 5.1 to 5.4)

By using steel pipes of the same lot as that of the example of the present invention as raw pipes, the push-to-pass process was experimentally performed in the same manner as that of the example of the present invention except that the shape conditions of the plug and die used in this example were changed as shown in Table 5.

(Conventional Example 5.1)

By using steel pipes of the same lot as that of the example of the present invention as raw pipes, a process by the cold drawing method shown in Fig. 2 was experimentally performed with a plug having a mirror surface and an all-in-one fixed type die. The shape conditions of the plug and the die used in this example are shown in Table 5. The plug was floated in the pipe. The thickness of the pipe at the outlet side of the die was set to 5 mm.

(Conventional Example 5.2)

By using steel pipes of the same lot as that of the example of the present invention as raw pipes, a process by the rotary forging press method shown in Figs. 3A and 3B was experimentally performed using a plug having a mirror surface and a rotary forming device provided with a segmented die. The shape conditions of the plug and the die used in this example are shown in Table 5. The plug was floated in the pipe. The thickness of the pipe at the outlet side of the die was increased to 7 mm.

Whether the productions by the methods of the above individual examples can be executed or not were evaluated, and the results are shown in Table 5. In addition, measured dimensional accuracy (deviation of the outer diameter, deviation of the inner diameter, and deviation of thickness) of product pipes produced by the method evaluated as a method used for production are also shown in Table 5. The deviation of the outer diameter and that of the inner diameter were obtained by performing image analysis of the cross-section of the pipe in the circumferential direction, and then calculating the maximum deviation (that is, (maximum diameter - minimum diameter)/diameter of the perfect circle × 100%)) deviated from the perfect circle in the circumferential direction. In addition, the deviation of the thickness in the circumferential direction was

obtained by performing image analysis of the cross-section of the pipe in the circumferential direction, and directly measuring the maximum deviation (that is, (maximum thickness - minimum thickness)/average thickness × 100%)) with respect to the average thickness from the image of the cross-section of the thickness.

As can be seen from Table 5, in all the examples according to the present invention, the push-to-pass process could be stably performed, and the dimensional accuracy of the product pipes was significantly superior. On the contrary, in the comparative examples, the push-to-pass process could not be performed, and no product pipes could be obtained. In addition, in the conventional examples, although the process could be performed, the dimensional accuracy of the product pipes was degraded.

Example 6

(Example 6.1)

By using steel pipes of YS400MPa as raw pipes, which had an outer diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m, manufacturing of a high dimensional accuracy pipe was experimentally performed by the push-to-pass process having the structure shown in Fig. 10 at a diameter reduction rate of 13%. At the initial stage of the manufacturing, a die having an angle of 21°, and a plug having an angle of 21° and a tapered length of 11 mm were

used. The plug was floated in the pipe. Onto the raw pipes before processing, a lubricant was applied by immersing the raw pipes in the lubricant in a coating bath. As the lubricant, a solvent solution containing a quick drying polymer lubricant was used.

In processing, the load in the push-to-pass direction was always measured by the measurement method described above, and the push-to-pass was performed while the measured load and the calculated load obtained by using the equation 4 were being compared with each other. In the equation 4 of this example, as the values of a and n, 0.00185 and 1 (corresponding to the case in which the pipe end condition is in free rotation) were used, respectively, which were the optimum values obtained beforehand by experiments.

When a second or later raw pipe was processed, since the measured load exceeded the calculated load, the process was determined not to be continued, and after the process was stopped, the process conditions were changed as follows. That is, the die and the plug were changed to a die having an angle of 11°, and a plug having an angle of 11° and a tapered length of 20 mm, respectively. The process was then restarted after this exchange, and the process for remaining raw pipes could be performed without any difficulty.

When the above exchange and restart of the process were performed, a part of the pipe in process at the inlet side

of the die and that at the outlet side were cut away, the pipe being placed in the die used before the exchange. In addition, the die used before the exchange was then removed from a predetermined fitting place, in which a part of the pipe was still in the die together with the plug used before the exchange. Subsequently, a die to be used was fitted to the same predetermined fitting place as above, and a plug to be used was charged in a raw pipe of the same YS which was to be processed and which had the same size as that used before, and the process was then restarted. In addition, the part of the pipe which was located at the outlet side of the die and was separated could be used as the product. The part of the pipe at the inlet side of the die was scraped.

(Comparative Example 6.1)

By using the same steel pipes as that in Example 6.1 as raw pipes, manufacturing of a high dimensional accuracy pipe was experimentally performed by the push-to-pass process having the structure shown in Fig. 10 at a diameter reduction rate of 13%. At the initial stage of the manufacturing, a die having an angle of 21°, and a plug having an angle of 21° and a tapered length of 20 mm were used. The plug was floated in the pipe. Onto the individual raw pipes before processing, a lubricant was applied by immersing the raw pipes in the lubricant in a coating bath. As the lubricant, a solvent solution

containing a quick drying polymer lubricant was used.

In processing, the measurement of the load in the push-to-pass direction was not performed, and an operator was delegated to judge whether the conditions were to be changed or not in an abnormal situation.

In processing a second or later raw pipe, since the die was cracked, after the process was interrupted, the die and the plug were exchanged with the same as those used at the initial stage, and the lubricant in the lubricant coating bath was totally changed to a solvent solution containing a quick drying polymer lubricant having a higher molecular weight. Subsequently, when the process was restarted, in processing a second or later raw pipe from the restart, the die was again cracked. Hence, the process was stopped, and the process conditions were changed as follows. That is, the die and the plug were changed to a die having an angle of 11°, and a plug having an angle of 11° and a tapered length of 20 mm, respectively. The process was restarted after this exchange, and the process for remaining raw pipes could be performed without any difficulty.

(Comparative Example 6.2)

By using the same steel pipes as that in Example 6.1 as raw pipes, manufacturing of a high dimensional accuracy pipe was experimentally performed by a drawing process at a diameter reduction rate of 13%. At the initial stage of the

manufacturing, a die having an angle of 21°, and a plug having an angle of 21° and a tapered length of 20 mm were used. The plug was floated in the pipe. For the individual raw pipes before processing, bonderizing treatment and application of metal soap were performed, and in addition, a meal pointing process (this metal pointing process was not necessary for the push-to-pass process) was performed for the front end of the pipe was performed, the process being essential for the drawing,.

In processing, the measurement of the load in the push-to-pass direction was not performed, and an operator was delegated to judge whether the conditions were to be changed to not in an abnormal situation.

In processing a second or later raw pipe, since the die was cracked, after the process was interrupted, the process conditions were changed as follows. That is, the die and the plug were changed to a die having an angle of 11°, and a plug having an angle of 11° and a tapered length of 20 mm. The process was restarted after this exchange, and the process for remaining raw pipes could be performed without any difficulty.

The conditions changed in processing, the relative process times, and losses in processing in the examples and comparative examples are shown in Table 6 in addition to the results of the dimensional accuracy of the products. The

relative process time is shown by the value obtained by dividing the time (total process time/total number of processed pipes) required for processing in each example by that in Comparative Example 6.1. The dimensional accuracy is shown by the deviation of the thickness and the deviation of the outer diameter. From the data obtained by image analysis of the cross-section of the pipe in the circumferential direction, the deviation of the thickness was obtained as the value with respect to the average thickness, and the deviation of the outer diameter was obtained as the value with respect to the perfect circle (target outer diameter).

As can be seen from Table 6, according to the present invention, a high dimensional accuracy pipe could be stably and efficiently manufactured.

Example 7

Hereinafter, the present invention will be further described in detail with reference to examples.

An apparatus of Example 7.1 was formed in combination of the plug 1, the die 2, and the pipe pushing device 3 as shown in Fig. 1, the plug 1 having a mirror surface to be brought into contact with the interior surface of a pipe, and having a diameter of 28 mm at the inlet side, a diameter of 30 mm at the central portion, and a diameter of 28 mm at the outlet side, the die 2 being an all-in-one fixed type

die in which the interior surface of the hole was mirror finished and the diameter thereof at the outlet side was 40 mm, the pipe pushing device 3 being formed of a hydraulic cylinder and being operated by either one of two operation modes, "continuous pushing" and "intermittent pushing". The plug 1 was used as a fixed plug which was fixed at one end thereof and which was charged in the pipe, and the operation mode of the pipe pushing device 3 was set to the "intermittent pushing". By the use of the apparatus described above, the push-to-pass of a carbon steel pipe having an outer diameter of 40 mm and a thickness of 6 mm was performed, thereby obtaining a pipe product having an outer diameter of 38 mm and a thickness of 6 mm.

In Example 7.2, except that the plug 1 was changed to a floating plug instead of the fixed plug, the push-to-pass process of a carbon steel pipe having an outer diameter of 40 mm and a thickness of 6 mm was performed in the same manner as that in Example 7.1, thereby obtaining a product pipe having an outer diameter of 38 mm and a thickness of 6 mm.

In Example 7.3, except that the operation mode of the pipe pushing device 3 was changed from the "intermittent pushing" to the "continuous pushing", the push-to-pass process of a carbon steel pipe having an outer diameter of 40 mm and a thickness of 6 mm was performed in the same

manner as that in Example 7.2, thereby obtaining a product pipe having an outer diameter of 38 mm and a thickness of 6 mm.

In addition, as Comparative Example 7.1, an apparatus having the structure as shown in Fig. 2 was formed in combination of a plug 5 which had a mirror surface to be brought into contact with the interior surface of a pipe, and which had a diameter of 28 mm at the inlet side, a diameter of 28 mm at the central portion, and a diameter of 26 mm at the outlet side, a die 6 which was an all-in-one fixed type die in which the interior surface of the hole was mirror finished and the diameter thereof at the outlet side was 38 mm, and a pipe drawing device 7 which was formed of a hydraulic cylinder, was operable in an "intermittent drawing" mode, and was able to apply a drawing force to the pipe in a predetermined operation mode. The plug 5 was a fixed plug which was fixed at one end thereof and which was charged in the pipe. By the use of the apparatus described above, the drawing of a carbon steel pipe having an outer diameter of 40 mm and a thickness of 7 mm was performed, thereby obtaining a product pipe having an outer diameter of 38 mm and a thickness of 6 mm. In Comparative Example 7.1, time and labor were required for making the steel pipe pass through the die hole after the front end thereof was narrowed.

In addition, as Comparative Example 7.2, except that the same plug 5 as that in Comparative Example 7.1 was used instead of the plug 1, and that instead of the die 2, a segmented die 9 (the inner diameter at the outlet side was equal to the diameter of the hole provided in the die 2 at the outlet side) incorporated in the rotary forging device 8 was used so as to form the structure shown in Fig. 3, a carbon steel pipe having an outer diameter of 40 mm and a thickness of 5 mm was pressed in the same manner as that in Example 7.1, thereby obtaining a product pipe having an outer diameter of 38 mm and a thickness of 6 mm.

The measurement results of the dimensional accuracy of these product pipes are shown in Table 7. The measurement methods for measuring the deviations of the thickness in the circumferential direction, the inner diameter, and the outer diameter shown in Table 7 are as follows.

The deviation of the outer diameter (or the inner diameter) was calculated as the maximum deviation with respect to the perfect circle from the distribution data of the outer diameter (or the inner diameter) measured by the steps of permitting a micrometer to be brought into contact with the outer diameter (or the inner diameter) of the pipe, and then rotating the pipe. The deviation of the thickness in the circumferential direction was directly measured as the maximum deviation with respect to the target thickness

from an image of the cross-section of the thickness. Instead of using the micrometer which was brought into contact the outer diameter or the like, the deviation of the outer diameter and the deviation of the inner diameter may be calculated from the distribution data in the circumferential direction of the distance between a laser generator and a pipe, which distance was measured by radiating laser light thereto. In addition, the deviation of the thickness in the circumferential direction may be calculated as the difference between the distribution data of the outer diameter in the circumferential direction and the distribution data of the inner diameter in the circumferential direction.

In addition, the deviation of the thickness (= deviation of the thickness in the circumferential direction), the deviation of the inner diameter, and the deviation of the outer diameter are defined as follows.

Deviation of thickness = (maximum thickness - minimum thickness)/target thickness (or average thickness) × 100 (%)

Deviation of inner diameter = (maximum inner diameter - minimum inner diameter)/target inner diameter (or average inner diameter) × 100 (%)

Deviation of outer diameter = (maximum outer diameter - minimum outer diameter)/target outer diameter (or average outer diameter) × 100 (%)

As can be seen from Table 7, according to the product pipes formed by using the apparatuses of Examples 7.1 to 7.3, significantly superior dimensional accuracy was obtained, and in particular, when floating was performed, the dimensional accuracy was further improved (Example 7.2). In addition, even when continuous push-to-pass was performed, a product pipe having a high dimensional accuracy was obtained (Example 7.3). On the contrary, by the conventional drawing, the dimensional accuracy of the product pipe was degraded (Comparative Example 7.1). By the pressing using the rotary forging device, the dimensional accuracy of the product pipe was also degraded (Comparative Example 7.2).

Example 8

(Example of present invention 8.1)

By using steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m as a raw material, as shown in Fig. 11, the push-to-pass process was performed. That is, a plurality of dies 2, 20, ---, 20 in conformity with dimensions of product pipes was set beforehand in a die rotating platform 19 in accordance with the order of pipes to be processed, the die 2 in conformity with the dimensions of the product of the preceding pipe 4 was then disposed in the pass line, the preceding pipe 4 was pushed in the die 2 by the pushing device 2 so as to complete the push-to-pass process, the plurality of dies was then sequentially moved

by rotating the die rotating platform 19, and the die 20 in conformity with the outside dimension of a product of the following pipe 7 was disposed in the pass line instead of the die 2. In the case described above, before the die 20 was disposed in the pass line, the plug 22 was charged in the following pipe 5, followed by the push-to-pass process performed by pushing the following pipe 7 in the die 20 by the pushing device 2. By repeating the steps described above, high dimensional accuracy pipes having various product dimensions were manufactured.

(Example of present invention 8.2)

By using steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m as a raw material, as shown in Fig. 12, the push-to-pass process was performed. That is, a plurality of dies 2, 20, ---, 20 in conformity with dimensions of product pipes was set beforehand in a die linear-driving platform 23 in accordance with the order of pipes to be processed, the die 2 in conformity with the dimensions of the product of the preceding pipe 4 was then disposed in the pass line, the preceding pipe 4 was pushed in the die 2 by the pushing device 2 so as to complete the push-to-pass process, the plurality of dies was then sequentially moved by linearly driving the die linear-driving platform 23, and the die 20 in conformity with the outside dimension of a product of the following pipe 7 was

disposed in the pass line instead of the die 2. In the case described above, before the die 20 was disposed in the pass line, the plug 22 was charged in the following pipe 5, followed by the push-to-pass process performed by pushing the following pipe 7 in the die 20 by the pushing device 2. By repeating the steps described above, high dimensional accuracy pipes having various product dimensions were manufactured.

(Comparative Example 8.1)

Steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m were as a raw material, a plurality of dies having different hole sizes was prepared, and the push-to-pass process was performed as shown in Fig. 13. The die 2 to be first used was disposed in the pass line, and the preceding pipe 4 was pushed in the die 2 by the pushing device 3 so as to complete the push-to-pass process. Next, by hand, the die 20 in conformity with the outside dimension of a product of the following pipe 7 was disposed in the pass line instead of the die 2. In this step, before the die 20 was disposed in the pass line, the plug 22 was charged in the following pipe 7. Subsequently, the push-to-pass process was performed by pushing the following pipe 7 in the die 20 by the pushing device 2. The process was repeatedly performed, and hence high dimensional accuracy pipes having various product dimensions were

manufactured.

(Comparative Example 8.2)

Steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m were used as a raw material, a plurality of dies having different hole sizes was prepared, and the push-to-pass process was performed as shown in Fig. 13. The die 2 to be first used was disposed in the pass line, and the preceding pipe 4 was pushed in the die 2 by the pushing device 2 so as to complete the push-to-pass process. Next, by hand, the die 20 in conformity with the outside dimension of a product of the following pipe 7 was disposed in the pass line instead of the die 2. In this step, the following pipe 7 was once moved outside the pass line, and after the plug 22 was charged therein, the pipe 7 was returned in the pass line. Subsequently, the push-to-pass process was performed by pushing the following pipe 7 in the die 20 by the pushing device 2. The process was repeatedly performed, and hence high dimensional accuracy pipes having various product dimensions were manufactured.

The process efficiency and the dimensional accuracy of the products according to the examples of the present invention and the comparative examples are shown in Table 8. The process efficiency was evaluated by the number of steel pipes processed by the push-to-pass per working hour, and in Table 8, the relative values thereof are shown which are

obtained when the process efficiency of Comparative Example 8.2 is set to 1. The dimensional accuracy was shown by the deviation of the thickness and the deviation of the outer diameter. These deviations were calculated from data obtained by image analysis of the cross-section of the pipe in the circumferential direction, the deviation of the thickness was the value with respect to the average thickness, and the deviation of the outer diameter was the value with respect to the perfect circle (target diameter).

As can be seen from Table 8, according to the present invention, the process efficiency was significantly improved.

Example 9

Hereinafter, the present invention will be further described in detail with reference to examples.

(Example 9.1)

As shown in Fig. 14, fine adjustment means 24 for adjusting pipe bending was provided at a position very close to the outlet side of the die 2. Although not shown in the figure, a continuous pushing device, which held the pipes 4 by endless tracks and continuously pushed them in the die 2, was provided at the inlet side of the die 2.

As shown in Fig. 15, the fine adjustment means 24 for adjusting pipe bending was formed so that a hole body 26 having a hole 27 through which a pipe was allowed to pass was movably supported by a support substrate 28 in the plane

perpendicular to the pipe traveling direction and so that at least one of four places of the periphery of the hole body 26 was pushed by a hole body-moving mechanism 29 supported by the support substrate 28 in the direction (hole body-moving direction 33) perpendicular to the pipe traveling direction. This pushing force was to be obtained by moving a wedge-shaped mold 30 having a tapered surface which was in contact with the periphery of the hole body in the pipe traveling direction by using an adjustment screw 31 which was engaged with the wedge-shaped mold 30. In Fig. 16, when the adjustment screw was turned clockwise, the wedge-shaped mold 30 was lifted, and the hole body 26 in contact with the tapered surface was moved to the left. In addition, after the fine adjustment of the hole body position was performed, fixing screws 32 were driven home, so that the hole body 26 was fixed to the support substrate 28.

By using this apparatus and steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m as a raw material, manufacturing of a high dimensional accuracy pipe was experimentally performed by the push-to-pass process in which this raw material was continuously fed in the die 2 while the plug 1 was being charged in the pipe and was being floated. The steel pipe after the push-to-pass process was allowed to pass through the hole 27 in the hole body 26 provided at a position very close to the outlet

side of the die 2. The hole 27 provided in the hole body 26 was a straight hole, and the diameter thereof was formed larger than that (in this example, the diameter was 35 mm) of the hole provided in the die 2 at the outlet side by 0.5 mm.

By using a plurality of dummy pipes before the actual manufacturing trial, push-to-pass process experiments were performed by changing the position of the hole body several times so as to measure the bending of the pipe, and the relationship between the change amount of the position of the hole body and that of the pipe bending after the push-to-pass was obtained. During the actual manufacturing trial, when the pipe bending was about to exceed a predetermined threshold, based on the above relationship, the hole body was moved in the direction so as to decrease the bending, that is, the fine adjustment of the hole body position was performed.

(Example 9.2)

As shown in Fig. 17, the fine adjustment means 24 for adjusting pipe bending was provided at a position very close to the outlet side of the die 2, a guide tube 35 was provided at a position very close to the inlet side of the die 2, and a guide tube 36 was provided at a position very close to the outlet side of the fine adjustment means 24 for adjusting pipe bending. Although not shown in the figure, a

continuous pushing device, which held the pipes 4 and continuously pushed them in the die 2 by endless tracks, was provided at an inlet side of the inlet-side guide tube 35.

As shown in Fig. 18, the fine adjustment means 24 for adjusting pipe bending was formed so that the hole body 26 having the hole 27 through which a pipe was allowed to pass was movably supported by the support substrate 28 in the plane perpendicular to the pipe traveling direction and so that at least one of four places of the periphery of the hole body 26 was pushed or pulled by the hole body-moving mechanism 29 supported by the support substrate 28 in the direction (hole body-moving direction 33) perpendicular to the pipe traveling direction. This pushing or pulling force was imparted by compact hydraulic cylinders 34 each of which was in contact with the periphery of the hole body 26. In Fig. 18, by adjusting the difference in pressure between the two opposing hydraulic cylinders 34, the hole body 26 was moved in the opposing direction between the above two hydraulic cylinders 34. After the fine adjustment of the hole body position, the difference in pressure between the two opposing hydraulic cylinders 34 was set to zero, so that the hole body 26 was fixed to the support substrate 28.

By using this apparatus and steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m as a raw material, manufacturing of a high dimensional

accuracy pipe was experimentally performed by the push-to-pass process in which this raw material was continuously fed in the die 2 while the plug 1 was being charged in the pipe and was being floated. The steel pipe before the push-to-pass process was allowed to pass through the inlet-side guide tube 35, and the steel pipe after the push-to-pass process was allowed to sequentially pass through the hole 27 in the hole body 26 provided at a position very close to the outlet side of the die 2 and the outlet-side guide tube 36. The hole 27 provided in the hole body 26 was a tapered hole, and the diameter thereof at the maximum inner diameter portion (located at the inlet side) was formed larger than the diameter (in this example, the diameter was 33 mm) of the hole provided in the die 2 at the outlet side by 2.5 mm. The diameter of the hole provided in the hole body 26 at the minimum inner diameter portion (located at the outlet side) was formed equal to that of the hole provided in the die 2 at the outlet side. In addition, in order to prevent the generation of faults on the pipe, the inlet-side and the outlet-side guide tubes 35 and 36 were formed so that the inner diameters thereof were larger than the outer diameters of the pipe at the respective sides by 0.5 mm.

By using a plurality of dummy pipes before the actual manufacturing trial, push-to-pass process experiments were performed by changing the position of the hole body several

times so as to measure the bending of the pipe, and the relationship between the change amount of the position of the hole body and that of the pipe bending after the push-to-pass was obtained. During the actual manufacturing trial, when the pipe bending was about to exceed a predetermined threshold, based on the above relationship, the hole body was moved in the direction so as to decrease the bending, that is, the fine adjustment of the hole body position was performed.

(Comparative Example 9.1)

As shown in Fig. 19, the guide tube 35 was provided at a position very close to the inlet side of the die 2, and the guide tube 36 was provided at a position very close to the outlet side of the die 2. In addition, although not shown in the figure, a continuous pushing device, which held the pipes 4 and continuously pushed them in the die 2 by endless tracks, was provided at the inlet side of the inlet-side guide tube 35.

By using this apparatus and steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m as a raw material, manufacturing of a high dimensional accuracy pipe was experimentally performed by the push-to-pass process in which this raw material was continuously fed in the die 2 (in this example, the hole diameter at the outlet was 33 mm) while the plug 1 was being charged in the

pipe and was being floated. The steel pipe before the push-to-pass process was allowed to pass through the inlet-side guide tube 35, and the steel pipe after the push-to-pass process was allowed to pass through the outlet-side guide tube 36.

(Comparative Example 9.2)

As shown in Fig. 20, nothing was provided at positions very close to the inlet side and the outlet side of the die 2. Although not shown in the figure, a continuous pushing device, which held the pipes 4 and continuously pushed them in the die 2 by endless tracks, was provided at the inlet side of the die 2.

By using this apparatus and steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m as a raw material, manufacturing of a high dimensional accuracy pipe was experimentally performed by the push-to-pass process in which this raw material was continuously fed in the die 2 (in this example, the hole diameter at the outlet was 35 mm) while the plug 1 was being charged in the pipe and was being floated.

(Comparative Example 9.3)

As shown in Fig. 21, nothing was provided at positions very close to the inlet side and the outlet side of the die 2. At the inlet side of the die 2, a pushing device was not provided, and at the outlet side of the die 2, a drawing

device 37 was provided.

By using this apparatus and steel pipes having a diameter of 40 mm, a thickness of 6 mm, and a length of 5.5 m as a raw material, manufacturing of a high dimensional accuracy pipe was experimentally performed by a drawing process in which the drawing device 37 held the front end of the pipe and drew it through the die 2 (in this example, the hole diameter at the outlet was 35 mm) in a drawing direction 38 while the plug 1 was being charged in the pipe and was being floated.

The pipe bending and the dimensional accuracy of the pipes manufactured by the methods of the examples and comparative examples described above were measured, and the results are shown in Table 9. For the measurement of the pipe bending, a linear ruler was placed along the pipe, and the evaluation was made by the maximum gap between the linear ruler and the central portion of the pipe per length of 500 mm thereof. The dimensional accuracy of the pipe was shown by the deviation of the thickness and the deviation of the outer diameter (in each example, the maximum value of the data of the manufactured pipes). These deviations were calculated from data obtained by image analysis of the cross-section of the pipe in the circumferential direction, the deviation of the thickness was the value with respect to the average thickness, and the deviation of the outer

diameter was the value with respect to the perfect circle (target diameter).

As can be seen from Table 9, according to the present invention, significantly superior dimensional accuracy was obtained, and in addition, the pipe bending after the push-to-pass could be sufficiently prevented.

Example 10

As an example of the present invention, a manufacturing line as shown in Fig. 22 was formed. Reference numeral 39 indicates a push-to-pass process device, and this device performs the push-to-pass process in which while the plug 1 is being charged in pipes and is being floated, the pipes are continuously fed in the die 2. This push-to-pass process device 39 was provided with a die exchange device 45, a plug exchange device 44, and a bending prevention device 46 which were formed as the preferable embodiments described above.

At the inlet side of the push-to-pass process device 39, from the upstream side, a pipe end-surface grinding device 40, a lubricant immersion coating bath 41, and a drying device 42 were disposed in that order. The pipe end-surface grinding device 40 was formed so that the end surfaces of pipes arranged on a table were cut using a grinding tool to make the end surface perpendicular to the pipe axis direction. The lubricant immersion coating bath 41 stored

an emulsion containing a drying liquid lubricant, and by immersing the pipe in the above emulsion bath, application of the lubricant to the pipe was performed. The drying device 42 was formed so that the pipes processed by lubricant application and then arranged on a table were dried by supplying a hot wind. In addition, at an inlet side of this manufacturing line, a pipe receiving table 47 was provided receiving raw pipes fed from the preceding step and sending them to the pipe end-surface grinding device 40, and at an outlet side, a pipe sending table 48 was provided sending pipes, which were formed into product pipes by the push-to-pass process, to the following step.

In this manufacturing line, the formation of the perpendicular angle of a pipe end-surface, lubricant immersion coating, drying, and push-to-pass process were performed in that order for raw pipes to which oxide scales still adhered and which had various sized, such as an outer diameter of 25 to 120 mm, a thickness of 2 to 8 mm, and a length of 5 to 13 m, thereby forming product pipes.

On the contrary, in Fig. 23, as a comparative example, a manufacturing line of a conventional drawing process is shown. In this manufacturing line, the pipe receiving table 47 was provided at an inlet side of a drawing process device 50 and the pipe sending table 48 was provided at an outlet side thereof, and the drawing process device 50 was a device

in which while the plug 1 was being charged in a pipe and was being floated, this pipe was drawn through the die 2. In addition, the drawing process device 50 was provided with the plug exchange device 44 and the die exchange device 45 which were formed as described in the example. In this manufacturing line, a raw pipe to which oxide scales still adhered as that of the example could not be drawn, and hence a pipe processed by a first pre-treatment process and the following second pre-treatment process must be used as the raw pipe.

The first pre-treatment process was essential as means for forming a strong lubricant film for the drawing process, and have many steps of cutting a raw pipe having scales thereon into short ones, removing scales by pickling, neutralizing an acid with alkali, washing with water, performing bonderizing treatment, applying metal soap, and drying, which were performed in that order. When a plurality of immersion baths or devices used for this first pre-treatment process was provided in the same line as that for the drawing process device 50, the productivity is decreased; hence, they were provided in a different line. In addition, the second pre-treatment process was essential as means for performing metal pointing of the front end of the pipe by a rotary forging device or the like so that the pipe was to be held by the drawing process device 50. When

this rotary forging device was provided in the same line as that for the drawing process device 50, the productivity is also decreased; hence, the rotary forging device was provided in a different line.

By using this manufacturing line of the comparative example, the drawing process was performed for pipes obtained by sequentially processing the same raw pipes having scales thereon as that in the example by the first and the second pre-treatment processes, thereby obtaining product pipes.

Times required for manufacturing and the dimensional accuracy of the product pipes of the example and the comparative example were measured, and the results are shown in Table 10. The time required for manufacturing was evaluated by the total treatment time/the total number of processed pipes, the total treatment time being a time required for obtaining product pipes from one lot of raw pipes, the lot containing a predetermined number of raw pipes. The relative values obtained when the evaluation value in the comparative example is set to 1 are shown in Table 10. The dimensional accuracy was shown by the deviation of the thickness and the deviation of the outer diameter. These deviations were obtained from data of image analysis of the cross-section of the pipe in the circumferential direction, the deviation of the thickness

was the value with respect to the average thickness, and the deviation of the outer diameter was the value with respect to the perfect circle (target diameter).

As can be seen from Table 10, according to the present invention, high dimensional accuracy pipes can be efficiently manufactured.

Industrial Applicability

A high dimensional accuracy pipe of the present invention has a significantly superior dimensional accuracy and hence also has a superior fatigue strength. In addition, since manufacturing can be performed at inexpensive cost, a superior advantage of greatly contributing to the reduction in weight of drive train parts of automobile and the like can be obtained. Furthermore, according to a manufacturing method of the present invention, a superior advantage can be obtained in which high dimensional accuracy metal pipes in response to wide requirements of sizes can be manufactured at inexpensive cost.

Table 1

	PROCESSING MODE	DIE	PLUG	DIAMETER REDUCTION RATE (%)	THICKNESS AT OUTLET SIDE	DEVIATION OF OUTER DIAMETER* (%)	DEVIATION OF INNER DIAMETER* (%)	DEVIATION OF THICKNESS IN CIRCUMFERENTIAL DIRECTION* (%)	CYCLES UNTIL ENDURANCE LIMIT IN FATIGUE TEST
EXAMPLE 1.1	PUSH-TO-PASS	ALL-IN-ONE FIXED	FIXED	10	EQUIVALENT TO THICKNESS AT INLET SIDE	0.5	0.5	0.5	500×10^3
EXAMPLE 1.2	PUSH-TO-PASS	ALL-IN-ONE FIXED	FIXED	5	EQUIVALENT TO THICKNESS AT INLET SIDE	0.7	2.5	0.7	500×10^3
EXAMPLE 1.3	PUSH-TO-PASS	ALL-IN-ONE FIXED	FLOATING	5	EQUIVALENT TO THICKNESS AT INLET SIDE	0.3	0.5	0.5	500×10^3
COMPARATIVE EXAMPLE 1.1	DRAWING	ALL-IN-ONE FIXED	FIXED	5	DECREASED THICKNESS	4.0	4.0	5.0	100×10^3
COMPARATIVE EXAMPLE 1.2	PRESSING	SEGMENTED ROTARY	FIXED	5	EQUIVALENT TO THICKNESS AT INLET SIDE	3.3	3.5	4.2	200×10^3
COMPARATIVE EXAMPLE 1.3	PRESSING	SEGMENTED ROTARY	FIXED	5	INCREASED THICKNESS	3.5	4.0	4.5	200×10^3

*DEVIATION FROM TARGET VALUE

Table 2

	PROCESSING METHOD	THICKNESS AT OUTLET SIDE	DEVIATION OF OUTER DIAMETER (%)	DEVIATION OF INNER DIAMETER (%)	DEVIATION OF THICKNESS IN CIRCUMFERENTIAL DIRECTION (%)	PROCESS EFFICIENCY: PROCESSABLE NUMBER PER ONE HOUR (PIPES)
EXAMPLE OF PRESENT INVENTION	PUSH-TO-PASS	EQUIVALENT TO THICKNESS AT INLET SIDE	0.5	0.5	0.5	130
COMPARATIVE EXAMPLE 2.1	DRAWING	DECREASED THICKNESS	4.0	4.6	5.0	40
COMPARATIVE EXAMPLE 2.2	ROTARY PRESS FORGING	INCREASED THICKNESS	3.8	4.0	4.5	60

Table 3

	PROCESSING METHOD	PRESENCE OF LUBRICANT FILM	LUBRICANT	GENERATION OF FAULTS	DEVIATION OF THICKNESS (%)	DEVIATION OF INNER DIAMETER (%)	DEVIATION OF OUTER DIAMETER (%)
COMPARATIVE EXAMPLE 3.1	PUSH-TO-PASS	NO	LIQUID LUBRICANT	YES	2.0	2.0	1.0
EXAMPLE OF PRESENT INVENTION 3.1	PUSH-TO-PASS	YES	LIQUID LUBRICANT	NO	0.5	0.5	0.5
EXAMPLE OF PRESENT INVENTION 3.2	PUSH-TO-PASS	YES	GREASE-BASED LUBRICANT	NO	0.5	0.5	0.5
EXAMPLE OF PRESENT INVENTION 3.3	PUSH-TO-PASS	YES	DRYING LUBRICANT	NO	0.3	0.3	0.3
EXAMPLE OF PRESENT INVENTION 3.4	PUSH-TO-PASS	YES	SOLVENT SOLUTION OF DRYING RESIN	NO	0.3	0.3	0.3
EXAMPLE OF PRESENT INVENTION 3.5	PUSH-TO-PASS	YES	EMULSION OF DRYING RESIN	NO	0.3	0.3	0.3
COMPARATIVE EXAMPLE 3.2	DRAWING	YES	LIQUID LUBRICANT	NO	4.5	3.5	3.5
COMPARATIVE EXAMPLE 3.3	PRESSING	YES	LIQUID LUBRICANT	NO	4.5	4.0	3.5

*ROTARY PRESS FORGING METHOD

Table 4

	PROCESSING METHOD	PIPE EXPANSION RATE %	DIAMETER REDUCTION RATE %	θA °	θB °	TARGET OUTER DIAMETER*2 mm	DEVIATION OF THICKNESS %	DEVIATION OF INNER DIAMETER %	DEVIATION OF OUTER DIAMETER %	CROSS-SECTIONAL HARDNESS Hv	OUTER DIAMETER AFTER PROCESSING mm	THICKNESS AFTER PROCESSING mm	REMARKS
1	PUSH-TO-PASS	8	8	4.95	4.97	40	0.3	0.3	0.3	320	40	6.0	EXAMPLE OF PRESENT INVENTION
2	PUSH-TO-PASS	6	8	3.64	4.85	39	0.25	0.3	0.3	320	39	6.0	EXAMPLE OF PRESENT INVENTION
3	PUSH-TO-PASS	1	17	0.59	9.88	34	0.15	0.2	0.2	320	34	6.0	EXAMPLE OF PRESENT INVENTION
4	DRAWING	-	8	0	4.85	39	5.0	4.0	4.0	200	39	5.8	COMPARATIVE EXAMPLE A
5	DRAWING	-	16	0	9.20	34	4.5	3.5	3.5	320	34	5.1	COMPARATIVE EXAMPLE B
6	PRESSING	-	8	0	4.85	39	4.5	4.0	3.5	200	39	6.2	COMPARATIVE EXAMPLE C

*1: ROTARY PRESS FORGING METHOD

*2: TARGET OUTER DIAMETER OF PIPE AT OUTLET SIDE OF DIE

Table 5

	PROCESSING METHOD	SHAPE CONDITIONS OF PLUG AND DIE: ANGLE OF PLUG DIAMETER-REDUCING PORTION (°)	SHAPE CONDITIONS OF PLUG AND DIE: LENGTH OF PLUG DIAMETER-REDUCING PORTION (mm)	SHAPE CONDITIONS OF PLUG AND DIE: LENGTH OF PLUG BEARING PORTION (mm)	SHAPE CONDITIONS OF PLUG AND DIE: ANGLE OF DIE (°)	EXECUTION OF MANUFACTURING	DIMENSIONAL ACCURACY: DEVIATION OF THICKNESS (%)	DIMENSIONAL ACCURACY: DEVIATION OF INNER DIAMETER (%)	DIMENSIONAL ACCURACY: DEVIATION OF OUTER DIAMETER (%)
EXAMPLE OF PRESENT INVENTION 5.1	PUSH-TO-PASS	21	11	20	21	YES	0.5	0.5	0.5
EXAMPLE OF PRESENT INVENTION 5.2	PUSH-TO-PASS	11	20	15	13	YES	0.5	0.5	0.5
EXAMPLE OF PRESENT INVENTION 5.3	PUSH-TO-PASS	5	90	4	5	YES	0.8	0.8	0.7
EXAMPLE OF PRESENT INVENTION 5.4	PUSH-TO-PASS	40	5	35	40	YES	0.3	0.4	0.3
COMPARATIVE EXAMPLE 5.1	PUSH-TO-PASS	<u>4</u>	11	4	4.5	NO	-	-	-
COMPARATIVE EXAMPLE 5.2	PUSH-TO-PASS	<u>45</u>	11	210	<u>45</u>	NO	-	-	-
COMPARATIVE EXAMPLE 5.3	PUSH-TO-PASS	21	<u>4</u>	4.5	21	NO	-	-	-
COMPARATIVE EXAMPLE 5.4	PUSH-TO-PASS	5	<u>105</u>	210	5	NO	-	-	-
CONVENTIONAL EXAMPLE 5.1	<u>DRAWING</u>	21	11	20	21	YES	4.5	3.5	3.5
CONVENTIONAL EXAMPLE 5.2	<u>ROTARY PRESS FORGING</u>	21	11	20	21	YES	4.5	4.0	3.5

Table 6

	PROCESSING METHOD	CONDITIONS CHANGED IN PROCESSING	RELATIVE PROCESS TIME	LOSS IN PROCESSING	DEVIATION OF THICKNESS (%)	DEVIATION OF OUTER DIAMETER (%)
EXAMPLE 6.1	PUSH-TO-PASS	SHAPES OF DIE AND PLUG	0.2	NO	0.5	0.6
COMPARATIVE EXAMPLE 6.1	PUSH-TO-PASS	TYPE OF LUBRICANT, SHAPES OF DIE AND PLUG	1	BREAKAGE OF DIE	0.5	0.6
COMPARATIVE EXAMPLE 6.2	DRAWING	SHAPES OF DIE AND PLUG	2	BREAKAGE OF DIE	3.5	3.2

Table 7

	PROCESSING MODE	DIE	PLUG	THICKNESS AT OUTLET SIDE	DEVIATION OF THICKNESS IN CIRCUMFERENTIAL DIRECTION (%)	DEVIATION OF INNER DIAMETER (%)	DEVIATION OF OUTER DIAMETER (%)
EXAMPLE 7.1	PUSH-TO-PASS (INTERMITTENT)	ALL-IN-ONE FIXED	FIXED	EQUIVALENT TO THICKNESS AT INLET SIDE	0.5	0.5	0.5
EXAMPLE 7.2	PUSH-TO-PASS (INTERMITTENT)	ALL-IN-ONE FIXED	FLOATING	EQUIVALENT TO THICKNESS AT INLET SIDE	0.4	0.5	0.3
EXAMPLE 7.3	PUSH-TO-PASS (CONTINUOUS)	ALL-IN-ONE FIXED	FLOATING	EQUIVALENT TO THICKNESS AT INLET SIDE	0.3	0.3	0.3
COMPARATIVE EXAMPLE 7.1	DRAWING (CONTINUOUS)	ALL-IN-ONE FIXED	FIXED	DECREASED THICKNESS	5.0	4.0	4.0
COMPARATIVE EXAMPLE 7.2	PRESSING (INTERMITTENT)	SEGMENTED ROTARY	FIXED	INCREASED THICKNESS	4.5	4.0	3.5

Table 8

	PROCESS EFFICIENCY	DEVIATION OF THICKNESS (%)	DEVIATION OF OUTER DIAMETER (%)
EXAMPLE OF PRESENT INVENTION 8.1	10	0.5	0.5
EXAMPLE OF PRESENT INVENTION 8.2	10	0.5	0.5
COMPARATIVE EXAMPLE 8.1	1.2	0.8	0.7
COMPARATIVE EXAMPLE 8.2	1	0.8	0.7

Table 9

	PROCESSING METHOD	BENDING PREVENTION MEANS	BENDING (mm)	DEVIATION OF THICKNESS (%)	DEVIATION OF OUTER DIAMETER (%)
EXAMPLE 9.1	PUSH-TO-PASS	FINE ADJUSTMENT MEANS FOR ADJUSTING PIPE BENDING AT POSITION VERY CLOSE TO OUTLET SIDE OF DIE	0.1	0.5	0.6
EXAMPLE 9.2	PUSH-TO-PASS	FINE ADJUSTMENT MEANS FOR ADJUSTING PIPE BENDING AT POSITION VERY CLOSE TO OUTLET SIDE OF DIE + INLET SIDE AND OUTLET SIDE GUIDE TUBES	0.2	0.5	0.6
COMPARATIVE EXAMPLE 9.1	PUSH-TO-PASS	INLET SIDE AND OUTLET SIDE GUIDE TUBES	0.7	0.5	0.6
COMPARATIVE EXAMPLE 9.2	PUSH-TO-PASS	MO MEANS	1.8	0.5	0.6
COMPARATIVE EXAMPLE 9.3	DRAWING	TENSION AT OUTLET SIDE IN DRAWING DIRECTION	0.3	3.5	3.0

Table 10

	PROCESSING METHOD	TIME REQUIRED FOR MANUFACTURING (RELATIVE VALUE)	DEVIATION OF THICKNESS (%)	DEVIATION OF OUTER DIAMETER (%)
EXAMPLE	PUSH-TO-PASS	0.1	0.5	0.6
COMPARATIVE EXAMPLE	DRAWING	1	3.5	3.2